MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVIII. *June* 14, 1878. No. 8.

Prof. A. CAYLEY, F.R.S., Vice-President, in the Chair.

M. Edouard G. Deville, Quebec; and
John Frederic Main, Esq., B.A., University College, Bristol;

were balloted for and duly elected Fellows of the Society.

On the late Opposition of Mars. By Maxwell Hall, Esq.
(*Extract from a Letter to the Astronomer Royal.*)

The contrast of the style of work to be performed in Transits and Oppositions is so strongly marked by my small telescope that for the future I shall pay attention to Oppositions alone, although Jamaica is well situated for some of the phases of the next transit of *Venus*.

You may perhaps remember that the observations made here during the last Opposition of *Mars* were so completely under control that they tested the going of the clock for very short intervals of time, and plainly showed that a good clock and a firmly mounted Equatoreal would give the solar parallax with great accuracy, in accordance with your article written in the year 1857.

I am awaiting the results of Mr. Gill's observations made with a Heliometer in the Island of Ascension; it would seem that they require some time for their reduction; and the system of triangulation of the comparison stars is certainly open to the objection that half the time and labour must be expended on the stars themselves instead of *Mars*, unless the triangulation is performed about midnight, when the circumstances of refraction will be different. In my extension of your method, by comparing *Mars* with two stars in the same sweep, one preceding and the other following, the work of connecting the stars together for

controlling the reductions is made a part of the observations of *Mars* for the determination of the parallax.

The Observatory, Jamaica,
1878, *May* 7.

Note on the Great Comet of 1861. By J. Tebbutt, Esq.

In many of the recent popular works on astronomy I have noticed that frequent references are made to the fact that European astronomers have shown that the Earth passed through, or very near, the tail of the great comet of 1861. As I was not in communication with the European scientific journals at the time of this comet's appearance, my discovery of it was not announced directly to them, nor were the results of my observations and calculations made known in the same way. I wish therefore to put on record as briefly as possible, in the *Monthly Notices*, that I claim to be not only the first observer of the comet, but also the first calculator of the elements of its orbit. Having assured myself by means of the imperfect instruments at my command that the object discovered on May 13, 1861, was really a comet, for it moved extremely slowly for some days, I announced the discovery to the Sydney Observatory on May 21, and in the *Sydney Morning Herald* of May 25. My approximate determination of the orbit from an observation at the Sydney Observatory, on May 24, and sextant observations by myself at Windsor, on June 3 and 11, appeared as follows in the *Herald* of June 15:—

Perihelion passage	June $13^{d}\cdot7253$ G.M.T.
Perihelion distance	0·82033
Longitude of ascending node	280° 0′ 44″
Longitude of perihelion on the orbit	252 13 39
Inclination of the orbit	86 18 42
Heliocentric motion	Direct.

In the same communication I pointed out the near approach of the Earth to the comet's tail for June 29, and also that the comet itself would probably become visible in full daylight. This announcement was followed by a more complete prediction by me in the *Sydney Empire* of June 22. The next published elements are those of the Rev. W. Scott, Government Astronomer, and Mr. H. S. Hawkins, M.A., of Goulburn, which appeared respectively in the *Herald* of June 27 and July 1.

As little seems to be known in the northern hemisphere respecting the early history of this comet, and as the newspapers which treat of it are of an ephemeral character, I have communicated this Note to the Society.

Windsor, N. S. Wales,
April 22, 1878.

Note on the Belgian Observations of the late Transit of Mercury. By Captain W. Noble.

In reply to a question addressed to me by our President, at the meeting of the Society on the evening of May 10, I expressed my belief that the determinations of the geographical position of the Observatory of M. de Boë at Antwerp, and of the local time there, were entirely trustworthy. I am now in a position to speak even more definitely, inasmuch as I have received a letter from the Baron von Ertbon, in which he says (I translate literally from the original) "that he (M. de Boë) has connected his Observatory by triangulation with the tower of Antwerp Cathedral, which is a point of the first order in the triangulation of the country. The co-ordinates then by reference to Brussels and Greenwich are rigorously known.

	m	s		°	′	″
Brussels is East of Greenwich	17	28·9				
From Brussels to M. de Boë's Observatory, East		9·7				
	17	38·6	Lat.	51	12	28.

The time was rigorously known. M. de Boë has a meridian circle by Secretan, with an objective of 2·56 inches aperture, a clock by Garnier, and a chronometer by the same artist, of which the error and rate are regularly observed and noted."

The Transit of Mercury, May 6, 1878. By John J. Plummer, M.A.

The transit of *Mercury* was observed at Orwell Park under unfavourable circumstances, but a better observation was secured than could have been expected. About noon light cirrus cloud overspread the sky, which became gradually denser until towards sunset, when rain fell heavily. For the few minutes during which the contacts were to be observed the clouds were decidedly thinner and the Sun could be well seen through a slightly tinted glass. The definition of the limb was, however, very bad and unsuited for scrutinising the phenomena of contact, and, although I was prepared to take micrometrical measurements, none were attempted in consequence.

	h	m	s
Greenwich mean time of external contact	3	11	34·2
„ „ internal „	3	14	19·7

The external contact was considered very good, but it is possible it may be 3 or 4 seconds late, as the undulations of the limb were so considerable that a little hesitation could hardly be avoided. The time of internal contact was the moment at

which light appeared permanently established in the rear of the planet without any distortion of the Sun's limb. Owing to the violent motion, it is possible that this time is one or two seconds too soon, but it is to be noted that my observation of the transit in 1868 left a precisely analogous impression on my mind at the time, namely that there was the reverse of clinging, or that the planet disengaged itself from the limb more suddenly and rather earlier than the progress of the phenomenon led the observer to anticipate. So far as the unfavourable atmospheric circumstances would allow, I note, therefore, no drop or ligament, no bright spot on *Mercury*, no aureola around the planet, and no distortion of either Sun or planet other than as produced by our atmosphere.

At $3^h\ 9^m\ 20^s \pm$ my wife, who assisted me at the observation, first detected the planet against the solar corona, though I had previously looked for it in vain. On taking my station at the telescope a minute later I also detected it, dimly visible, but sufficiently so to direct my attention to the exact point where contact was to take place, and to lead me to suppose that, but for the clouds through which the observation was made, it would have been fairly conspicuous. Full aperture employed 10 inches, focal length 12 ft. 9 in., power 303.

Orwell Park Observatory,
May 31, 1878.

Observations of the Transit of Mercury, May 6, 1878, *at Dunecht Observatory.* By Lord Lindsay and Dr. Copeland.

Until about half-an-hour before the beginning of the transit the day was very fine, with a fresh breeze from the S.S.E. About this time light drifting clouds began to appear, and increased in density until the Sun was at times wholly obscured. Just before first contact, however, the clouds gradually assumed a more fleecy character, and the Sun reappeared with rapidly increasing brightness. Thus it happened that first contact was seen through an appreciable layer of cloud, which was nearly swept away before the planet had fully entered on the Sun's disk. Except perhaps for photographic purposes, the sky was practically clear for the rest of the day.

Five telescopes were used in the observations, besides photographic apparatus. Lord Lindsay and Mr. Ranyard observed with the spectroscope; Mr. Ranyard also made eye observations along with Messrs. H. J. Carpenter, J. G. Lohse, and Dr. Copeland, while Mr. Davis took a series of photographs.

The observations are here given under five heads, in the succession adopted in Lord Lindsay's circular of April 16.

Section 1.—*Eye Observations of* 1*st and* 2*nd Contacts.*

Mr. Ranyard at the time of first external contact was employed with the spectroscope. His time of internal geometrical contact, recorded by an assistant, is $6^h\ 2^m\ 15^s{\cdot}5$. Mr. Ranyard remarks: "At the time I called the word *contact*, it seemed to me that the two disks (i.e. the disk of *Mercury* and the Sun's disk) were in geometrical contact. I did not see the bridge of light separating the planet from the limb till about another second had elapsed." The instrument used was the 15·06 inch Grubb refractor, reduced to 10 inches, carrying a power of 380 on a Merz polarizing eye-piece.

Mr. H. J. Carpenter observed with a Newtonian unsilvered glass reflector of 12·9-inches aperture, having a total reflecting prism for the 2nd reflexion. Power used throughout 171. His notes are:—

"Owing to cloud, the first glimpse I got of the planet on the Sun's limb was at $5^h\ 59^m\ 30^s{\cdot}5$. By estimating the time when *Mercury* had encroached on the disk as much again as when first seen, I put the time of first external contact at $5^h\ 59^m\ 14^s{\cdot}5$ sidereal time. At $6^h\ 2^m\ 14^s{\cdot}4$ *Mercury* was fully on the Sun's disk. The time given is that when a thread of light seemed to come between the Sun's limb and *Mercury*; this phenomenon was almost instantaneous. The images were very bad, and I could not say that I detected any ligament or any alteration of the circular form of *Mercury*. I could not see *Mercury* outlined against the sky, nor detect a halo round it."

Mr. J. G. Lohse, using a 4-inch by Cooke, with a power of 60, gives "First external contact $5^h\ 59^m\ 11^s{\cdot}8$, probably one second late. Internal contact certainly past at $6^h\ 2^m\ 17^s{\cdot}3$; time given probably too late by 15^s to 20^s. Definition of limbs very bad at internal contact. The observation difficult, on account of a very obvious ligament. In accordance with the foregoing, I put

	h	m	s
External geometrical contact	5	59	10·8
Internal „ „	6	1	59·8

Dr. Copeland, observing with a 6-inch telescope, object, glass by Simms, mounting by Dallmeyer, and a power of 126-recorded—

	h	m	s
Just perceptible indentation	5	59	12·8
Apparent geometrical contact	6	2	7·3
Distinct and instantaneous rupture of ligament	6	2	19·3

After internal geometrical contact I was surprised to see a distinct clinging between the limb of *Mercury* and that of the Sun, thus forming a distinct narrow ligament. This ligament broke instantaneously at the moment given. The planet was

then seen at an appreciable distance from the Sun's limb. The ligament was merely a faint grey shading, which might easily have been overlooked. It totally disappeared on breaking.

Section 2.—Spectroscopic Observations of Contact.

Lord Lindsay used a 6-inch Equatoreal by Cooke, within the focus of which was a direct-vision prism.* This threw a dispersed image of the Sun on the slit of an automatic spectroscope, by Browning, capable of giving an effect of from 2 to 10 prisms. The distance between the slit and the direct-vision prism in the tube was 13·1 inches. The length of the direct-vision prism is $3\frac{1}{2}$ inches. These dimensions are measured along the axis of the tube. The slit and the refracting angle of the direct-vision prism being set perpendicular to the Sun's limb, an arc of the Sun's limb depending in length on the power used is seen extending along the spectrum, and in fact tinted with the corresponding colours of the spectrum. In addition the bright lines of the chromosphere are seen projecting beyond the Sun's limb. By moving the telescope any part of the Sun's limb may be made to appear in any colour that may be wished. In this way the point where *Mercury* was expected was brought into the region of the C line.

Immediately before first contact the apparatus was further arranged as follows:—

Light passing twice through two half prisms of the Browning spectroscope, equivalent deviation 103° for line D, dispersion 8° 7′·2 from C to *h*. Magnifying power of eye-piece on viewing telescope 3, giving an effect of 45 on the whole instrument. The recorded observations are

h	m	s	
5	58	13	Sun's limb barely visible.
5	58	46·4	First glimpse of the planet on the reversed C line.
5	59	0·4	External contact on the C line.

The increasing brightness of the Sun rendering an addition to the dispersive power of the spectroscope imperatively necessary, Lord Lindsay made the requisite changes; when this was done it was unfortunately "found that the second contact was lost."

Mr. Ranyard had attached to one of the finders (aperture 3·74 inches) of the 15-inch refractor a Grubb compound prism spectroscope, dispersion C to *h* 5° 40′, magnifying power 55. With this instrument Mr. Ranyard, looking for *Mercury* outside the Sun's limb in the red end of the spectrum, could detect no indications of the presence of the planet off the Sun's disk.

* Dispersion from C to *h*, 10° 58′·4. In what follows, the magnifying powers and instrumental constants are substituted for the numbers or letters actually recorded by Lord Lindsay; in other respects his notes are strictly reproduced.—R. C.

Section 3.—*Observations of Cusps.*

No measures of cusps were taken. All the observers agree that no brush or streak of light extending round or partly round the planet was visible during Egress. Except in the case of Lord Lindsay's observations, no indication of the planet was seen outside the limb of the Sun.

Section 4.—*Observations of the Planet when on the Disk of the Sun.*

After an internal contact, the sky becoming still clearer, Lord Lindsay changed the spectroscope to an effective dispersion of 6 prisms, giving 24° 21′·6 from C to *h*, the magnifying power being at the same time increased to 57. $6^h\ 4^m$ and $6^h\ 11^m$ the planet was viewed in the colour of the E line, with the note, "Disk of planet round, sharp, clear, clean."

At $6^h\ 20^m$, with the same arrangements, Lord Lindsay adds: "I see no sort of halo; haze very thick; wide slit." The greatest opening possible is 0·032 inch. Lord Lindsay's further observations are:—

At $7^h\ 7^m$. "Still with 6 prisms but with a power of 136; with this higher power there is a distinct decrease of darkness from the centre of *Mercury* outwards."

At $7^h\ 21^m$. "As before, but viewed on the C line, the shading off from the centre is most marked, with decreased aperture, and shows best with 1·63-inch aperture, mean of 6 measures with the Iris diaphragm."

$7^h\ 50^m$ to $7^h\ 55^m$. "Spectroscope removed; with Browning achromatic eye-piece, power 270, and medium sunshade, I get diffraction rings, with an aperture of 1·42 inch. With aperture 3·45 inches *Mercury* is perfectly clean and round, but, whether from contrast or not, the limb is decidedly brighter, or rather less dark than the centre."

$8^h\ 5^m$ sid. time. "I have just tried powers 92 and 174, and find the shading much less apparent than with a higher power. With a power of 382 it is marked. I get no trace of a bright spot."

"No satellite."

With an aperture of 10 inches and powers 244, 381 and 563, Mr. Ranyard looked carefully for rings round the planet or spots upon its disk, without seeing either. When the image of the planet was thrown on the slit of the finder spectroscope no other change was perceptible except the appearance of a black streak traversing the spectrum from end to end, caused by the interruption of the light.

Mr. H. J. Carpenter says: "I could not see *Mercury* outlined against the sky, nor detect a halo round it, nor a satellite, although I looked carefully with the 15-inch (reduced to 10 inches), as well as with the reflector."

Dr. Copeland found the planet plainly visible with so small an aperture as 0·4 inch, but much shaded off at the limb. This seems to be the chief effect of applying small diaphragms. With an aperture of 0·95 inch some traces of a bright spot in the centre of the planet's disk were perceived. With the same aperture and telescope Mr. Ranyard thought he saw a greyish ring round the planet. It was the only diaphragm that produced any trace of a bright central spot.

Mr. J. G. Lohse, with the 4-inch Cooke, power 60, measured the distance of the centre of the planet from the Sun's limb, as follows:—

Dunecht Mean Time. h	m	s	Dist. ′	″	Position Angle. °
3	7	52·2	0	20·73	45
	12	50·2	0	38·84	45
	16	17·2	0	56·61	45
	20	38·3	1	14·45	43·7
	30	18·3	1	46·44	43·7
	32	20·3	1	56·83	43·7
	36	31·3	2	9·35	41·73
	40	26·3	2	24·56	41·73
	44	8·3	2	37·15	41·73
	49	30·3	3	2·97	41·73

And the diameter of *Mercury*—

1st. With the full aperture—

$10''{\cdot}87 \pm 0''{\cdot}29$, 5 measures.

2nd. Aperture reduced to 1·7 inch.

$11''{\cdot}98 \pm 0''{\cdot}16$, 12 measures.

Dr. Copeland, with a power of 126 on the 6·06-inch Simms object-glass, found the diameter of *Mercury* to be as follows:—

Diam. of ☿. ″	Aperture. in.	Pos. Angle. °	No. of meas.
10·84	6·06	45	2
10·73	3·60	124	4
10·53	3·60	34	8
9·40	0·95	...	1

The twelve measures with the aperture reduced to 3·6 inches give a mean of $10''{\cdot}597 \pm 0''{\cdot}099$, corresponding to a diameter of $5''{\cdot}916$ at the mean distance of the Sun.

Mr. H. J. Carpenter, with the 12·9-inch reflector and a power of 171, obtained measures of the diameter of *Mercury* with a mean result of $12''{\cdot}43$.

All the observations have been corrected for refraction where

necessary, and the periodic errors of the screws have been eliminated.

5. *General Remarks.*

As a check on the values of the micrometer screws used to measure the size of *Mercury*, the chief pair of Σ 1090 has been measured:

1. By Mr. J. G. Lohse with the 4-inch:

Distance $60''\cdot69 \pm 0''\cdot39$; 12 measures.

2. By Dr. Copeland with the 6·09-inch:

Distance $60''\cdot80 \pm 0''\cdot11$; 11 measures.

Position $98^\circ\cdot08 \pm 0^\circ\cdot11$; 16 measures.

As a further check the same pair of stars were measured by Mr. J. G. Lohse with the Grubb 15-inch, full aperture.

Distance $60''\cdot57 \pm 0''\cdot12$; 9 measures.

Position $97^\circ\cdot56 \pm 0^\circ\cdot08$; 9 measures.

A combination of these determinations gives for Σ 1090

	″	°
1878·37	Dist. 60·685,	Pos. 97·73, A and B.

One measure of distance and two of position with the 6-inch gave for the third star

	″	°
1878·37	Dist. 20·82,	Pos. 319·75, B and C.

With the same telescope A was 7·9 mag. yellowish, B 8·5 white, and C 10·5 mag.

The hour angle was too great and the companion stars unfortunately too faint to be measured with the unsilvered reflector.

The focal lengths of the telescopes used are approximately as follows:—

		in.
15·06	Grubb refractor	183·2
12·9	Reflector	122·5
6·06	Simms refractor	74·5
6·04	Cooke „	90·3
4·00	„ „	59·5
3·74	Grubb finder	43·8

The best four of about twenty photographs have been measured, but the final results have not yet been deduced. It is worthy of remark that the image of *Mercury* appears much

smaller in the photographs than it did on the ground glass of the camera.

The latitude of Dunecht by transit-circle observations is 57° 9′ 36″; the longitude, taken from the Ordnance Survey map, is 9^m 40^s west of Greenwich. The time was determined with the transit circle on several nights both before and after the day of the transit. Unless otherwise stated, the times are given in Dunecht sidereal time.

Dunecht, June 12, 1878.

Observations of the Transit of Mercury of 1878, *May* 6.

By A. C. Ranyard, Esq.

The transit was observed by me at Dunecht. Lord Lindsay kindly gave me the use of his 15-inch refractor, which was stopped down to ten inches during the observation, in order to avoid all chance of damaging the eye-pieces or dark shades by the Sun's heat. On one of the finders was a spectroscope, with a single compound prism, by Grubb, with a dispersion of 5° 56′ from *B* to *h*. On the other finder was a low-power eye-piece, with cross wires, which were brought into accurate collimation with the centre of the slit of the spectroscope. On the large instrument was a Merz polarising eye-piece, giving a power of 244.

As the planet came up to the Sun's limb, from about ten minutes before the time of predicted contact, I observed the spectrum of the sky in the direction in which the planet was approaching. The viewing telescope of the spectroscope was turned so that the red end of the spectrum below C was in the field of view, and the slit of the spectroscope, which subtended an arc of 5′ 45″ upon the Sun, was nearly at right angles to the path of the approaching planet. The slit was swept outward in right ascension over the path of the planet, and any variation in the brightness of the field corresponding to the place of the planet was carefully looked for. My reason for attempting this observation was that M. Janssen, in observing the transit of *Venus*, thought that by making use of a screen of blue glass he had been able to detect the body of the planet projected upon the background of the corona some time before it was visible without the screen. As far as I am aware, there are no observations which indicate that the spectrum of the lower parts of the corona is richer in blue rays than the spectrum of the light derived from the veil of illuminated particles floating in our own atmosphere, which under ordinary circumstances hides the corona from our view. Indeed the evidence is rather in the contrary direction, for Mr. Stone, observing during the total eclipse of April 1874, was of opinion that the continuous spectrum of the lower parts of the corona was rich in red light. I therefore

thought it better to examine the red end of the spectrum, but I did not succeed in detecting any indication of the position of the planet before it came up to the Sun's limb. It should, however, be remembered that the sky was until first contact covered with thin clouds, which were at times sufficiently thick greatly to diminish the Sun's light.

I continued my observations at the spectroscope until some time after the signal for first contact had been given, and having satisfied myself that I could not see any longitudinal streak or variation in the brightness of the spectrum corresponding to the outer limb of the planet in the field of the spectroscope, I turned to the larger instrument with the Merz polarising eye-piece.

The planet had now entered quite one-third of its diameter upon the Sun's disk, and the sky was rapidly clearing, but I was unable to see any trace of the outer limb or any portion of the planet which was not projected upon the Sun's disk.

I then passed back again to the spectroscope and watched until the planet was about two-thirds upon the Sun's disk, but saw nothing to indicate the position of the outer limb in the field of the spectroscope.

On turning again to the large instrument with the Merz eye-piece, only a small arc of the planet remained off the Sun's disk. The sky was now clear and the definition was very good, but I could not see any trace of the part of the planet off the Sun, and I certainly could not see any line of light around the outer limb of the planet as described by some of the transit of *Venus* observers. I continued to watch with the Merz eye-piece turning the field alternately brighter and darker until the planet was entirely upon the Sun's disk, and I gave the signal for geometrical contact at the moment when the disk of *Mercury* and the disk of the Sun appeared to have a common tangent. There was no sticking or any appearance that could be described as a black drop, and in another second—certainly in less than two seconds—after the signal I saw a bridge of light separating the planet from the Sun's limbs. The time of my signal as taken down by an assistant, who, however, neglected to observe the minute, corresponds to $6^h\,[2^m]\,15^s{\cdot}5$ Dunecht sidereal time. When *Mercury* was upon the Sun's disk I carefully looked for rings round the planet and for the spot of light which has been observed in former transits upon the disk, but could not detect any trace of either the rings or the spot of light; but in observing afterwards with a cardboard diaphragm of less than an inch in diameter upon the instrument used by Dr. Copeland I thought that I at times saw a greyish ring round the planet, but did not feel quite certain as to its existence.

When the planet was well advanced upon the Sun's disk, the slit of the spectroscope was placed so as to bisect the disk of the planet, and the black band, which was then visible running longitudinally across the field of the spectroscope, was carefully examined; but neither Dr. Copeland, who assisted me in this

observation, nor I, could detect any alteration in the solar spectrum at the edges of the band. The slit of the spectroscope was then shifted by pressure upon the side of the instrument until the slit cut off a small arc or was nearly tangential to the disk of the planet, but no changes in the solar spectrum at the edges of the band could be perceived.

The difficulties of the observation (owing to the small magnifying power and to the atmospheric tremor) were, however, so great that no reliance must be placed on this observation as affording any but the roughest evidence that the planet has not a very large absorbing atmosphere.

In the evening after the transit the collimation of the spectroscope and finder was tested upon a star and found not to have shifted, so that there can be little doubt that the slit was swept over the place of the planet as it came up to external contact.

Observations of the Transit of Mercury, 1878, *May* 6.

By Maxwell Hall, Esq.

(*Extract from a Letter to the Astronomer Royal.*)

The transit of *Mercury* was observed here yesterday under circumstances well worth your consideration. The Ingress was obscured by a cloud, but the Egress showed that no reliance could be attached to the estimated times of the various phases of contact, δ, ϵ, ζ, geometrical contact and bisection; they were all so linked together that the time of any phase was liable to an error of about 10 seconds.

A party of ladies and gentlemen assembled here to see the transit, and the results are most curious and entertaining. With a low power of 55 most of us saw a ring of light, brighter than the surface of the Sun, surrounding the black disk of *Mercury*; with a higher power of 120 some of us saw both the ring and a bright central spot, some saw only the ring, some only the spot, and some neither. With a power of 200 I myself distinctly saw the spot in the form of a *small* and *narrow ring* of light, concentric with the black disk of *Mercury*, and about $5''$ in diameter; but with this power I found that the *exterior ring had vanished.*

The sketch made by Dr. Huggins during the transit of *Mercury* in 1868 (*Monthly Notices*, vol. xxix., p. 27) was carefully compared with what we saw with the intermediate power, and, excepting the eccentric position of the bright spot in that sketch, it was generally approved of as representing our combined descriptions.

There cannot therefore be the least doubt that these appearances are merely optical; and they were only seen by those who had the more delicate eyesight.

A first-surface solar prism and a dark glass shade were employed; the diameter of the object-glass is 4 inches.

The Observatory, Jamaica,
1878, *May* 7.

Observations of the Transit of Mercury, May 6, 1878, *at Princeton, N. Jersey. Lat.* 40° 20′ 58″·0 ± 0″·2, *Long.* 9^{m} 36^{s} ± 1^{s} *E. of Washington.* By Professor C. A. Young.

The instrument used was the new Clark E quatoreal, of 9½ inches aperture, armed with a Merz polarising solar eye-piece. The whole aperture was employed. The magnifying power at the first observation was 155; all the rest were made with a power of 223.

Flying clouds were troublesome, and the seeing was very bad, from the unsteadiness of the air, but the phenomena took place with a rapidity and decisiveness quite in contrast with what I had seen at the transit of *Venus*, so that I think the probable error of the times given cannot much, if at all, exceed one second.

The timepiece used was a sidereal clock beating once in two seconds. Its errors were carefully determined by star observations on the nights preceding and following the transit, and it was compared with the solar clock by means of the chronograph.

The solar clock was also compared with Washington time by means of the telegraphic noon signals which are sent daily to New York. By the kindness of Mr. Merrihew, the Superintendent of the Eastern Division of the Western Union Telegraph Company, these signals were transmitted over the wire which passes into the Princeton office for several days preceding the transit and on the day of the transit. The time was carried from the Telegraph Office to the Observatory by means of a pocket chronometer. The telegraphic comparisons were not, however, quite satisfactory, owing to interruptions from unskilled operators on the line, who broke it continually; but the approximate longitude stated above, and derived from these comparisons, agrees well with that deduced from the coast survey maps.

The first contact (external) at Ingress was noted at

h	m	s		h	m	s	
1	11	35·7	Sid. =	22	14	13·9	Pr. M.T. Magnifying power 155.

The second contact (internal) at

h	m	s		h	m	s	
1	14	27·7	Sid. =	22	17	05·4	Pr. M.T. Magnifying power 223.

At 1^{h} 12^{m} 41^{s}·7 Sid. or 22^{h} 15^{m} 29^{s}·7 M.T. was noted the

Ingress of the estimated centre of the planet, but the observation was not very satisfactory.

At $1^h\ 14^m\ 34^s{\cdot}7$ Sid. $= 22^h\ 17^m\ 12^s{\cdot}4$ M.T. the Ingress was certainly past. During the seven seconds between this moment and that noted as the moment of internal contact there was some quivering and flickering of the luminous band between the limb of the planet and that of the Sun. The contact was noted at the instant when the black connection between the planet and Sun's limb *first* broke, which it did pretty suddenly.

At Egress the internal contact was noted at

h	m	s		h	m	s	
8	42	06·3	Sid. or	5	43	30·7	Princeton Mean Time.

The external contact (through flying clouds) at

h	m	s		h	m	s	
8	44	54·3	Sid. or	5	46	18·3	Princeton Mean Time.

Both observations were satisfactory, though the seeing was very bad. There was an interval of about 4^s at the internal contact, during which the band of light between the edge of the planet and the Sun was flickering, the time noted being that when several dark filaments first shot across. Two seconds earlier the band began to waver and change its appearance, and two seconds later it was quite certain that the contact was past. The external contact was equally definite.

The seeing was exceedingly bad, the limbs both of the Sun and planet being deeply serrated by the action of a strong cold N.W. wind, so that I was and still am surprised at the decisiveness and promptness with which the phases presented themselves.*

During the transit I examined the planet carefully with various powers from 100 to 500, and although the granulations of the Sun's disk often showed beautifully at moments of good seeing, I could make out nothing like a ring of light around the planet nor anything like a bright spot upon its disk. Once or twice, when the definition was specially good, I thought I could see that close around the planet there was a tendency to an apparent radiating structure of the solar "rice grains," as if the atmosphere of the planet had some elongating action upon their images. This is, however, just the opposite of the effect refraction would produce, and on the whole I fancy the apparent effect was wholly subjective.

The colour of the disk was a dark violet, exactly the same as that of a Sunspot seen with the same polarising eye-piece, or with a Herschel solar eye-piece and shade of "London smoke."

During the transit about 80 measures of the planet's diameter were made by bringing the disk between different sets of slightly

* Other observers here, with smaller telescopes of apertures between 3 and 4 inches, saw the "black drop" phenomenon most conspicuously. Dr. Alexander reports that the "black drop" at Ingress was so troublesome as to render his observation of contact entirely unsatisfactory.

converging lines, or rather bands, photographed on glass. The bands were made wide enough to destroy the effect of irradiation upon the planet's disk. There were six different sets of bands, and the observations were made by three different persons—Mr. W. Libbey, jun., Professor Rockwood, and myself. The magnifying powers were varied from 155 to 500, most of the observations being with the highest power.

A preliminary reduction, the results of which may be slightly, but only slightly, changed by a more complete discussion, gives the diameter of the planet, from set 1, $11''{\cdot}89$; set 2, $11''{\cdot}59$; set 3, $11''{\cdot}85$; set 4, $11''{\cdot}79$; set 5, $11''{\cdot}76$; and set 6, $11''{\cdot}56$. The general mean is $11''{\cdot}74$. The tabular diameter of the American Almanac is $11''{\cdot}99$.

Princeton, May 13, 1878.

Observations of the Transit of Mercury.

By S. P. Langley, Director of the Allegheny Observatory.

(*Communicated by E. Dunkin, Esq., F.R.S.*)

The Transit of *Mercury* of May 6 was observed here under the favourable circumstance of an exceptionally transparent blue sky in the early part of the day, which enabled some observations to be made which seem worth record.

The principal instruments were an achromatic of 13-inch aperture, with a polarising solar eye-piece, which gives images free from colour without the use of shade glasses; for photometry, a Jamin photometer, used with a camera attached to the telescope; for heat, the special apparatus used heretofore on the thermal measurements of Sunspot nuclei. In the field of the polarising eye-piece was a glass reticule, ruled in squares, whose sides were $15''$ each. Powers of from 120 to 800 were employed through the day at the eye-piece, and the image of the planet, greatly enlarged, was also projected on a white surface in the dark camera. The following are the chief results:—

(1) The entire disk of the planet was seen outside the Sun at about 30^s before first external contact, on a just perceptibly lighter background.

(2) The true diameter, which I suppose to have been seen under these circumstances, was estimated, by aid of the reticule, to be $\frac{1}{5}$ larger than that exhibited directly after, when the planet had entered on the Sun. (1st external contact, $21^h\ 52^m\ 50^s{\cdot}43$ Allegheny M.T., by chronograph.)

(3) There was momentarily good definition at first internal contact ($21^h\ 55^m\ 47^s{\cdot}25$ by chronograph, Allegheny M.T.), but no black drop or ligament was seen by me. (An assistant, using a 4-inch achromatic, with dark glass, saw a ligament, and observed contacts from 5 to 15 seconds later.)

(4) No bright spot or annulus was seen during the day.

(5) The planet was not seen black, as it has been often called. The light was not materially less than that of some Sunspot nuclei, but bluish grey, and measured 8 per cent. at the least of mean sunlight. (This will possibly be subject to a subsequent correction for imperfect achromatism.)

(6) There was unquestionable evidence of heat from the same direction.

(7) The planet was darker at the centre than at the edge, but in the photometric observations this was proved beyond question to be chiefly due to minute and rapid atmospheric tremor.

The following inferences seem obvious. From (1) we must conclude that the coronal background made its presence sensible without an eclipse to at least 15″ from the limb. From (2) that a correction of something like 20 per cent. is to be added to micrometric eye-measures of *Mercury* on the Sun, for irradiation. (4) The observation of these in previous transits rests on testimony not to be set aside. It may be asked, then, whether the condition of visibility is not an unusually good definition, like that enjoyed by Mr. Huggins in 1868. The definition, as regards steadiness, was here only ordinarily fair most of the day, though in the forenoon the transparency of the sky was, as has been remarked, unusual. (5) and (6) are to be interpreted, of course, not as evidence of light and heat actually radiated from *Mercury*, but as data for estimating with something like precision a lower limit for the effects of our own atmosphere in inflecting the *solar* radiation, and as giving useful quantitative results for the effects of "atmospheric glare." To make a single application: admitting that this atmospheric glare was like a bright veil, spreading eight per cent. of sunlight over both *Mercury* and the corona, and admitting also that the eye demanded at least one per cent. of excess of brightness in the background to make *Mercury* visible—we must evidently conclude that the actual brightness of the Inner Corona exceeds (at any rate) one one-thousandth of that of direct sunlight; or, as we may say in other words, the Inner Corona is several hundred times the average brilliancy of the full Moon.

Allegheny Observatory, Allegheny, Pa.,
May 13, 1878.

The Transit of Mercury, 1878, *May* 6, *observed at the Astro-physical Observatory, Ó-Gyalla, Hungary.* By Dr. Nicolas de Konkoly, Member of the R. Academy, Budapest.

(*Communicated by Mr. H. M. Christie.*)

There were five observers of the Transit: to prevent them from being under the influence of each other, they were dispersed in the Park near the Observatory.

I observed with my $6\frac{1}{4}$-inch Refractor, provided with clockwork and a polarising solar eye-piece, by Merz of Munich. My assistant, Dr. Schrader, observed the contacts with the $10\frac{1}{4}$-inch Reflector Equatoreal by Browning, with a Browning double reflecting solar eye-piece; Capt. Reviczky observed with a large comet-finder, azimuthally mounted, with an aperture of $4\frac{1}{2}$ inches; Mr. Alexander Cvet, from Russia, observed with a 3-inch achromatic, by Bardoux of Paris; Lieut. Horwáth with a $3\frac{1}{2}$-inch comet-finder; and Mr. T. Kaiser, Engineer, with an achromatic telescope of nearly 4 inches.

After the contact observations I measured right ascension differences with Dr. Schrader. I made my measures with the $6\frac{1}{4}$-inch Merz, with a Browning filar-micrometer; and Dr. Schrader measured with the Heliograph, which has an object-glass of 3 inches by Reinfelder and Hertel of Munich. This instrument is mounted and constructed only for observing the Sun, and is provided also with exquisite clockwork.

The contacts were observed as follows:—

First Contact.

Name of Observer.	Greenwich M.T. h m s	Ö-Gyalla M.T. h m s
Lieut. Horváth	3 12 10·4	4 24 56
Alexander Cvet	3 12 31·4 [?]	4 25 17 [?]
Joseph Kaiser	3 12 7·4	4 24 52

Second Contact (*Inner*).

Name of Observer.	Greenwich M.T. h m s	Ö-Gyalla M.T. h m s
Lieut. Horváth	3 14 31·4 [?]	4 27 17 [?]
Alexander Cvet	3 13 58·4 [?]	4 26 43 [?]
Joseph Kaiser	3 13 44·4	4 26 30
Dr. Schrader	3 13 45·4	4 26 31
Dr. Konkoly	3 13 45·4	4 26 31

Capt. Reviczky saw nothing of the phenomena. He had badly arranged the Barlow lens and eye-piece in the telescope supplied to him.

None of the observers saw the planet before it touched the Sun's limb, and no one observed either the "black drop" or an aureola round the planet, or any white spot upon its surface.

I measured six transits of east–west limb from Sun and *Mercury*, and my assistant, Dr. Schrader, measured ten. All transits were noted on the chronograph as follows:—

Observer: Konkoly.

No.	Ö-Gyalla M.T. h	m	s	Greenwich M.T. h	m	s	Δ ☿ − ⊙ m	s	No. of Webs as observed.
I	4	45	0·1	3	32	14·5	+0	42·64	7
II	4	56	12·7	3	43	27·1	+0	39·67	5
III	5	1	12·9	3	48	27·3	+0	38·60	7
IV	5	26	42·9	4	13	57·3	+0	32·36	7
V	5	44	0·1	4	31	14·5	+0	27·97	6
VI	5	47	53·2	4	35	7·6	+0	27·33	7

Observer: Schrader.

No.	Ö-Gyalla M.T. h	m	s	Greenwich M.T. h	m	s	Δ ☿ − ⊙ m	s	No. of Webs as observed.
I	4	34	37·9	3	21	52·3	+0	45·19	3
II	4	37	18·9	3	24	33·3	+0	44·49	5
III	4	40	7·9	3	27	22·3	+0	44·07	5
IV	4	49	11·8	3	36	26·2	+0	41·50	5
V	4	52	1·7	3	39	16·1	+0	40·94	5
VI	5	12	39·2	3	59	53·6	+0	35·55	5
VII	5	15	28·1	4	2	42·5	+0	35·09	4
VIII	5	30	54·7	4	18	9·1	+0	31·10	7
IX	5	33	55·3	4	21	9·7	+0	30·23	7
X	5	59	13·1	4	46	27·5	+0	24·07	6

The differences are yet free [*sic*] from atmospheric refraction. I have also given Greenwich mean time to facilitate the comparison of my observations with English observations. The Δ ☿ − ⊙ is mean solar time.

The Heliograph is a new instrument, installed on the 1st of November of last year in the smaller drum of the Observatory. It is mounted equatoreally on a stone pillar, with driving clockwork apparatus. There is no continuous tube, but a framework of steel and brass rods for supporting the object-glass and the eye-glass: the Sun's image is more steady than in an instrument with a wooden or brass tube. The object-glass is one of the best quality, made by Reinfelder and Hertel of Munich.

The Ö-Gyalla Observatory is $1^h\ 12^m\ 45^s{\cdot}59$ E. of Greenwich; the latitude is $47°\ 52'\ 43''{\cdot}0$ N.

Ö-Gyalla Observatory,
1878, *June* 8.

On the Mean Solar Parallax as derived from the Observations of the Transit of Venus, 1874.

By Captain G. L. Tupman, R.M.A.

(*Communicated by the Astronomer Royal.*)

In order that astronomers may judge of the manner in which I have treated the question in this paper, and form an opinion of the value of the result obtained, it is necessary that they should be in possession of the original observations. Those made by the British Government Expeditions were published in detail in the Report presented to Parliament by the Astronomer Royal, and are supposed to be sufficiently accessible, especially as the important parts of them are quoted in Mr. Stone's Paper in the *Monthly Notices* for March last (vol. xxxviii., p. 279). The following are similar verbatim extracts from all the other reports received up to the present time at the Royal Observatory.

Mr. Stone, Her Majesty's Astronomer at the Cape of Good Hope, observed with the 7-inch Equatoreal, power 200, shade not stated. The sky was perfectly clear of cloud; there was no wind, and the definition was good.

Egress.

The times near contact were taken down from a chronometer by Mr. Freeman, and, to avoid all possible effects of bias, no attempt was made by the observer to count the seconds between the different phenomena observed. As *Venus* approached the Sun's limb, signals were given at different intervals indicating that no disturbance of the Sun's limb near the point of contact had taken place.

	h	m	s	
At	19	6	25·0	Cape mean time, some disturbance of the limb was first suspected. An examination immediately after this showed that the suspicion was unfounded. There was no appearance of any ligament.*
At	19	7	12·0	the connexion between *Venus* and the Sun's limb was first established. It was now seen continuously, and of a fair breadth.†
At	19	7	29·6	apparent contact not perfect; but the ligament of considerable breadth.
At	19	8	5·0	apparent contact.

* This is the language in which Mr. Stone's observation was originally communicated to the Astronomer Royal. In his paper in the *Monthly Notices* for April last Mr. Stone has given $19^h\ 6^m\ 25^s$ as a *good* observation.

† It must be kept in mind that *breadth* applied to a ligament, shadow, or connection between the limbs is measured in a direction parallel to the limbs; but when applied to the ring of light round the planet, or to the faint band joining the cusps of the Sun, it is measured perpendicular to the limbs—G.L.T.

"With respect to the first contact I should not be surprised to find that observers with less powerful optical means, or who have employed denser absorbing media to reduce the brightness of the image than employed by me, may not have observed the ligament at so considerable a distance between the apparent limbs of *Venus* and the Sun as I have done; but there is no doubt whatever about the ligament having been seen by me continuously from the time noted, $19^h\ 7^m\ 12^s{\cdot}0$.

The time given for apparent contact is when the curvature of the limbs, those of *Venus* produced, appeared to touch. It was exceedingly difficult to fix the times with great certainty on account of the very slow changes in the form depending on the oblique motion of *Venus* across the disk."

Mr. Finlay, the First Assistant at the Cape, observed with the 4-inch Refractor, power 180.

		h	m	s	
Real	contact at *egress* at	19	7	11·0	Cape mean time.
Apparent	„ „	19	8	18·5	„

"The time noted as that of 'real contact' is when I first noticed a slight connection between *Venus* and the Sun, while *Venus* still seemed to be within the Sun's disk. At this time the ligament was about as broad as it was long.

This ligament continued to increase in breadth till the time noted as that of 'apparent contact,' when the limbs were considered to coincide. I found some difficulty in judging this time accurately, and was inclined to give the signal for it more than once before the time noted: the contact was decidedly established when I did give the signal. From recollection I should say that at this time the ligament was rather less than a semidiameter of *Venus* in breadth. Probably the observation is several seconds late."

[The Cape observers do not mention, nor do their diagrams show the illumination in the planet's atmosphere joining the cusps of the Sun.]

Mr. Maclear, observing with the Transit Theodolite by Troughton & Simms, aperture 1·65 inch, diagonal eye-piece, power 23, recorded "first appearance of actual permanent connection between the dark limb of *Venus* and the Sun" at $19^h\ 7^m\ 48^s$ Cape mean time.

Mr. H. L. Spindler observed at Fort Frederick, Port Elizabeth, latitude 33° 57′ 59″ S., longitude $1^h\ 42^m\ 28^s{\cdot}8$ E. (by the Cape Trig. Survey), with a $3\frac{1}{2}$-inch achromatic by Troughton & Simms, "showing the Sun direct image." Power and colour of dark glass not stated. Time was communicated by telegraph from the Cape Observatory.

Egress.

h m s
At 19 7 7·5 *Cape* mean time the contact seemed so nearly perfect that only a thin dark line along the edge of the Sun proved the contact hardly consummated.

[In reply to a query from Mr. Stone, dated 1875, March 5, three months after the transit, Mr. Spindler explains that he unthinkingly used the word "dark" line instead of "bright" line, and he further states that "the last time a clear *bright* line of division was perceptible would be about 5 seconds before the first time recorded," or at $19^h\ 7^m\ 2^s{\cdot}5$ C.M.T.]

h m s
At 19 7 17·5 the appearance of the limbs was as though blended in one sharp defining line, hence set down as the moment of perfect contact.

At 19 7 33·0 the contact may be described simply as fully perceptible or certain, but with no observable loss of circular form in any appreciable degree. I believe, on a reconsideration of all the circumstances, a few seconds added to the second time ($19^h\ 7^m\ 17^s{\cdot}5$) will be the true moment of apparent internal contact.

Mr. D. Gill, of Lord Lindsay's expedition, observed at Belmont, Mauritius, latitude 20° 2′ 57″ S., longitude $3^h\ 50^m\ 41^s{\cdot}0$ E., (Gill) with a 4-inch achromatic, by Cooke, and Merz polarising eye-piece, power 150.

Egress.

"The internal contact was observed at $21^h\ 48^m\ 12^s{\cdot}5$ local mean time. A few seconds previous to what was noted as contact a light grey shade appeared between the limbs of the Sun and planet. This appeared to become black almost at the same time as geometric contact. I only observed this time; but I think it may be four or five seconds in error, as there was no precise phenomenon to observe."

Dr. R. Copeland, at the same place, observed with a 6-inch achromatic, solar diagonal, power about 100. Sun's limb boiling.

"Last internal contact—formation of ligament seemed identical with geometrical contact, and can scarcely be uncertain to more than two seconds—at $21^h\ 48^m\ 11^s{\cdot}3$ Belmont mean time."

Mahmoud Bey, Astronomer to his Highness the Khedive, at the Observatory at Abbasseyeh, lat. 30° 4′ 38″·1, long. $2^h\ 5^m 8^s{\cdot}9$ E. (Browne), observed with an Equatoreal of about 6 inches aperture.

Egress.

	h	m	s	
Distinct formation of ligament	20	11	13·2	Local mean time.
Internal geometrical contact	20	12	18·7	„ „

Colonel Tennant observed at Roorkee, in lat. 29° 51′ 33″·8 N., long. $5^h\ 11^m\ 33^s{\cdot}4$,* with a 6-inch Equatoreal by T. Cooke & Sons, fitted with a solar diagonal.

The whole of the time the tremor was very great.

"The *Ingress* was observed with the double-image micrometer eye-piece, power 128, neutral tint glass and solar diagonal. The contact of limbs was observed at $12^h\ 42^m\ 26^s{\cdot}1$ local sidereal time. Possibly there was some confusion from the two images, though *one* was clear, and there was a good deal of atmospheric disturbance.

"I saw no peculiarity: the contact took place without any black drop or distortion. At the moment it occurred I was endeavouring to get hold of the tappet or key, and in doing so lost count; but I looked up at once at the dial (and allowed for lost time) when I was sure that the critical phenomenon had really passed without any of the peculiarities I had been led to expect. This estimated interval was three seconds, and I think that all causes of error would be included in ascribing a probable error of two seconds to the observation of time.

"The *Egress* was observed with a Huyghenian eye-piece, power 205, with yellow-green (chlorine) glass on the diagonal prism. The final line of light was very fine, and I can only describe its disappearance by saying that it melted away. The vanishing occupied a sensible portion of time, but very small. It was too short for me to be able to say that there was any veil or lessening of the brilliancy of the line of light. There was no black drop or distortion; I saw no projection of *Venus* on the background. The contact was observed at $16^h\ 28^m\ 36^s{\cdot}1$ local sidereal time."

Captain Strahan† observed at Lahore, latitude 31° 23′ 23″·5 N., longitude $4^h\ 57^m\ 20^s{\cdot}1$ E., with a 6-inch Equatoreal by Troughton & Simms, negative power 125, on solar diagonal.

Egress.

"As the planet moved towards the Sun's limb, she appeared to push away his edge before her, the cause of which became evident in a few seconds; the planet's edge was, in fact, encircled

* Adopting General Addison's correction to the old longitude of Madras, which is the point of reference of all the longitudes of the Great Trigonometrical Survey.—G.L.T.

† Col. Tennant's Report. p. 35.

by a ring of light nearly as bright as the Sun, which prevented any contact, properly so called, from taking place at all. The moment I have assumed for internal contact, and recorded as 'slight darkness between the limbs,' was when the Sun's light, unbroken by the ring of light, would just have grazed the limb of *Venus*. This was at $16^h\ 14^m\ 36^s{\cdot}9$ local sidereal time; some uncertainty about the minutes; seconds correct; no black drop; the darkness enveloped more of the limbs without increasing in depth (of shade); no dark ligament occurred at all. I have considerable confidence in the accuracy of this observation, as the limbs were beautifully steady and sharp, and no distortion apparent."

Captain A. C. Bigg-Wither observed at Mooltan, latitude 30° 11′ 5″ N., longitude $4^h\ 46^m\ 1^s{\cdot}8$ E.,* with a 4-inch achromatic by Cooke, solar diagonal, power 55 for *Ingress*.

"The Sun rose with the planet about half-way on to its disk, and even at internal contact it was too near the horizon to be well seen; with power 55, however, I satisfied myself that the 'black drop' was formed, the apparent internal contact being at about $12^h\ 14^m\ 42^s$ Mooltan sidereal time, the black band joining the planet's disk with the darkness of space being then about 20″ broad; the real internal contact was at $12^h\ 17^m\ 8^s$ M.S.T. about, the black band with a breadth of about 7″ being then apparently broken."

Egress.—"As *Venus* approached the Sun's limb, she appeared to push before her a ring of light concentric with her disk; there was absolutely no internal contact whatever, no formation of a black drop, and no distortion of the apparent shape of the planet's disk."

Mr. Hennessey† observed at Mussoori, in the Himalayas, latitude 30° 27′ 36″·3, longitude $5^h\ 12^m\ 12^s{\cdot}2$ E, and height above the sea 6,765 feet, with a 5-inch Equatoreal, power 125.

At *Ingress* the Sun was $7\frac{1}{2}°$ above the horizon; internal contact was noted at $14^h\ 17^m\ 9^s$ *Greenwich* mean time.

Egress was observed with a red glass. Neither pear-drop nor ligament, nor any other connection or shadow, appeared between the limbs, until at last the two fairly touched at $18^h\ 5^m\ 32^s{\cdot}6$ G.M.T.

General Addison observed at Kurrachee, lat. 24° 50′ 58″·4, long. $4^h\ 27^m\ 53^s{\cdot}4$ E. (*Monthly Notices*, vol. xxxviii., p. 83), with a 5-inch Equatoreal by Cooke, power 117.

	h	m	s	
Internal contact at *Egress*	15	44	10·9	Local sidereal time.

* Captain Bigg-Wither gives no authority for the longitude. Supposing it to be taken from the Indian Survey, I have increased it $2^s{\cdot}3$ (Addison's correction). How the local time was obtained is not stated.—G.L.T.

† *Proceedings of the Royal Society*, No. 159.

From the Madras Observatory, lat. 13° 4′ 8″·1 S., long. $5^h\ 20^m\ 59^s{\cdot}6$ E. (Addison), Mr. Pogson reports of *Egress*:—

"Just about 3rd contact the clouds grew a little thinner, and the contact was noted by

	h	m	s	
Miss E. J. Pogson at	23	24	32	Madras mean time.
C. R. Chary at	23	24	46	„ „
T. M. Pillay.	23	25	12	„ „

probably some mistake about the last.

"The two first observers both agreed that no black drop was visible, but through such clouds I only wonder they saw the contact at all."

Mr. A. V. N. Row observed at Vizagapatam, lat. 17° 42′ 9″ N., long. $5^h\ 33^m\ 30^s$ E. (authority not given, probably depends upon the Trig. Survey, and I have increased it to $5^h\ 33^m\ 32^s{\cdot}3$), with a 6-inch Equatoreal by Cooke, solar diagonal *and double parallel wire micrometer with its eye-piece No. 2. One of the wires was kept a tangent to the Sun's limb at the point of contact*, and in this way the internal contact at *Egress* was noted at $16^h\ 47^m\ 15^s{\cdot}4$ local sidereal time.

At Melbourne Observatory, Mr. Ellery observed with the 8-inch Equatoreal by Troughton & Simms, negative eye-piece of 125, with Herschelian prism and yellowish smoke-tint dark glass. Sun free from clouds.

Ingress.

	h	m	s	
At	23	59	39	Melbourne mean time. Apparent coincidence of limbs of Sun and *Venus*, or tangential contact.
At	0	0	10·9	"Chinaman's Cap," an appearance generally seen with the artificial transit, but was only faintly seen for an instant in the actual transit; it is like a very obtuse triangle with its broad base towards the Sun's limb, whilst its apex touches *Venus*, the two similar sides being curved towards the base and towards each other.
At	0	0	26·0	first appearance of occasional flicker of light between the limbs. A streak of light was occasionally seen to glimmer clear between the planet and the Sun's limb; this soon gave way to the next appearance.
At	0	0	44·8	appearance of smoky junction of limbs, a broad band as if of thin smoke occupied the space between the limbs. This gradually gathered up as it were, till it became like a very thin thread, which was now and then invisible, although the limbs of planet and Sun were very well defined and steady. It appeared sharper and thinner at last.
At	0	1	9·4	sudden disappearance or rupture of the very thin dark thread joining the limbs.

"In these observations I was surprised at the absence of any (except a mere trace) of the appearances nearly always seen in the artificial transit, and which were fully expected in the actual transit. The phases were all clear and sharp, but the motion of *Venus* being so slow and oblique, it impressed me that it was impossible to assign the time of the true internal contact to within two or three seconds of time with any certainty, even when the edges of the two bodies were almost perfectly quiescent and as sharp as two disks of metal."

Egress. Eye-piece the same as at Ingress.

	h	m	s	
At	3	26	57·6	Melbourne mean time, haze or smoky appearance first seen to join limbs of Sun and *Venus*. The smoky junction appeared very faint at first but unsteady as regards width, sometimes narrow, at other times as wide as one-third the diameter of the planet. It was never black, but only like a thin smoke.
At	3	28	14·0	first saw a distinct thread in centre of haze. The thread was much darker than the smoke, less defined and more nebulous than at ingress.
At	3	29	3·7	tremulous junction of limbs, due to the disturbed state of the atmosphere, and boiling of the edges of the Sun and *Venus*, whereby they appeared at one instant joined and then separated, a slight haze always appearing at the separation.
At	3	29	20·0	distinct junction of limbs, when they no longer appeared to separate by the tremulous motion.

Mr. White, the First Assistant at Melbourne Observatory, observed as follows, with an *Altazimuth* of $2\frac{3}{4}$ inches aperture, with 4-glass diagonal positive eye-piece and red glass shade.

[Power not stated, but it would probably be only 30 or 40.]

Ingress.

	h	m	s	
At	23	58	42·	Melbourne mean time, estimated tangential contact. *Venus* appeared to be attached to the Sun by a very broad ligament nearly as black as the planet itself.
At	23	59	46·	"Chinaman's Cap." At this time the ligament narrowed very much on the side of *Venus*, the broad part being still attached to the Sun's limb.
At	0	0	44·	bright thread of light, estimated contact. A bright arc of light appeared between the broad part of the "cap" and the Sun's limb. The Sun was now clouded for 17 seconds, and when the cloud had passed, the "cap" had disappeared and *Venus* had become truly circular, and was well separated from the limb of the Sun.

Egress.

At	3	28	24·	cap thrown out. A dusky triangular figure was thrown off from *Venus*, the apex being towards the planet and the base towards the nearest part of the Sun's limb. The "cap" in this instance did not appear to be nearly so black as at ingress.

	h	m	s	
At	3	29	15·	thread of light destroyed (contact). The cap came into contact with the Sun's limb, at the same time the apex had continually increased in breadth.
At	3	30	16·	tangential contact estimated. Similar to ingress.

The late Professor Wilson observed at Mornington, about 30 miles from Melbourne, in lat. 38° 13′ 54″ S., long. $9^h\ 40^m\ 8^s{\cdot}73$ E. (Ellery), with a $4\frac{1}{2}$-inch Equatoreal, negative eye-piece of 145, with Herschelian prism and neutral tint wedge. Time communicated by telegraph from Melbourne Observatory.

"The Sun was clouded all the time, and I had to keep the wedge constantly working from end to end. Where the clouds were thinnest the definition was very good, and there was no boiling edge. *The times recorded are not epochs selected during a continuous sight of the ingress, but the phenomena seen at glimpses obtained at intervals.*"

Ingress.

	h	m	s	
At	23	59	43·7	Melbourne mean time, circle of *Venus* tangent to Sun's limb.
At	0	0	39·5	broad band.
At	0	1	23·4	quite clear of limb. Only an instantaneous view through a great deal of cloud. The fluffy connection seemed gone, but might perhaps have been still there if a clear view had been obtained.

Egress.

The sky was clear, there was much boiling, and the definition was not nearly so good as at ingress.

	h	m	s	
At	3	27	36·2	first appearance of a small dark object flickering backwards and forwards between the limbs. This increased, and there was no other phase to which I could attach a definite time.
At	3	29	31·4	I gave a signal, and named it "broad band," but the flickering object had gradually changed into this. *Venus* never assumed the appearance of being a tangent to the Sun's limb as at ingress.

Mr. C. Moerlin, Second Assistant at Melbourne Observatory, observed at View Hill, Sandhurst, about 86 miles N.W. of Melbourne, in lat. 36° 48 16″·9 S., long. $9^h\ 37^m\ 12^s{\cdot}8$ E. (Ellery), with a $6\frac{1}{2}$-inch Equatoreal, negative eye-piece of 120, Herschelian prism, and neutral tint wedge. Time telegraphed from Melbourne.

Ingress lost through clouds.

Egress.

The Sun's limb and the planet appeared sharp and well defined through thin cloud. The streak of light between them, distinct and unmistakable, became smaller, and

h	m	s	
At 3	29	36·6	Melbourne mean time, all at once a sort of triangular shaped connection between the two took place, an appearance I have seen with the artificial transit, but to a more limited extent, the base of the triangle on the Sun's limb and the apex on the planet. The difference in the appearance from that which I have seen with the artificial transit consists in the much larger base. The planet every once in a while jumped off the apex of the triangle, and a thin line of the Sun's disk could be distinctly seen between the two, the distance, however, between the triangle and the planet, when jumping, growing less. I now looked out for tangential contact, watching at the same time the gradual diminution of the separation between the planet and the apex of the triangle. The clouds became thicker, but still permitted me to see the phenomenon distinctly.
At 3	30	0·1	tangential contact. The jumping or separating of the apex of the triangle and the planet ceased a few seconds before what I considered the tangential contact.

Mr. Gilbert, Fourth Assistant at Melbourne Observatory, observed at Glenrowan, about 150 miles N.E. of Melbourne, in lat. 36° 28′ 4″ S., long. $9^h\ 44^m\ 53^s{\cdot}3$ E. (Ellery), with a $4\frac{1}{2}$-inch Equatoreal by T. Cooke & Sons, negative eye-piece of 120, Herschelian prism, and neutral tint shade. Time by telegraph from Melbourne.

Ingress.

h	m	s	
At 23	58	53·	Melbourne mean time, the ligament commenced to form. The Sun now disappeared behind a cloud for about 20 seconds.
At 23	59	59·	the ligament was well defined.
At 0	0	34·	apparent contact of limbs.
At 0	0	42·5	the ligament snapped suddenly.
At 0	0	50·	a clear line of light between the limbs.

"The snapping of the ligament I consider an excellent observation, the objects being so well defined."

Egress lost through cloud.

Mr. Morris observed at the same place as Mr. Gilbert, with an $8\frac{1}{2}$-inch Browning-With Reflector, negative eye-piece of 150, Herschelian prism. [Shade not stated.]

	h	m	s	
At	23	57	17·	first noticed the ligament. It became more distinct, and was not so dark as the planet itself. It gradually lessened in width.
At	0	0	45·8	it was so narrow and filmy that it was scarcely perceptible. Before the rupture was observed clouds obscured the Sun. The ligament seemed in fact to melt away gradually.

Mr. Russell, at the Sydney, N.S.W., Observatory, lat. 33° 51′ 41″·1 S., long. 10ʰ 4ᵐ 47ˢ·3 E. (Stone, *Monthly Notices*, xxvii. 299), observed with the 11½-inch Equatoreal, by H. Schröder, with the aperture reduced to 5 inches, direct vision eye-piece of 100 (in preference to the reflecting eye-piece). The coloured glasses were green before the eye-piece and dark blue next the eye.

[It is inferred that all the times inserted in the reports of the Sydney observers are Sydney mean times, although it is nowhere so stated.]

Ingress.—Sky clear, definition good.

	h	m	s	
At	0	20	0·	[Sydney mean time] indications of distortion, or bad definition of the limbs in contact appeared, like a mass of black wool laid over the place, rendering it impossible to see distinctly, and making the cusps very hazy. I thought the drop was going to form, and watched very closely for it, and for apparent contact; but I found it extremely difficult to make up my mind about the latter, and saw nothing of the former.
At	0	20	51·	was noted a very unsatisfactory apparent contact. The cusps after this appeared to clear up or improve in definition, and as they approached each other the sharpness was very remarkable, but the motion was so gradual I could not determine to a fraction of a second when they actually formed the line of light which I saw complete and took for the moment of internal contact; but the instant I was sure of the line I made the record on the
	0	23	59·	chronograph (0ʰ 23ᵐ 59ˢ), and keeping my eye steadily
	0	24	14·	upon it, saw it had, in 15 seconds, become a distinct and unmistakable band of sunlight.

Egress.—Sky clear, definition good generally, at times bad.

	h	m	s	
At	3	53	53·6	the limb of the planet nearest to the Sun's limb seemed to be in a state of vibration, as if portions of its blackness were jumping over to the margin of the Sun. This lasted only a few seconds, the vibrations being estimated at 6 or 7 per second; after this the limbs recovered their perfect definition, and were clearly and steadily separated
	3	54	26·3	by a line of light, which, at 3ʰ 54ᵐ 26ˢ·3, could not have been more than half a second of arc in thickness, and then, the same marvellous definition continuing, just when it was wanted, the line gradually contracted to a scarcely
	3	54	39·7	visible thread and the limbs made contact at 3ʰ 54ᵐ 39ˢ·7. There was no sudden break; nothing but the perfectly gradual motion of the one disk over the other, both beautifully defined. I have no doubt that had the bad definition continued, the moment when the jumps were seen would have been taken as the formation of the drop.

"A curious phenomenon then presented itself, similar to that remarked at ingress; the two limbs at the point of contact seemed to get confused or badly defined, whether from atmospheric causes near us or from some peculiarity about *Venus* I am unable to say, but it seemed to distort the planet in a remarkable way, and now, at Ingress, I found it very difficult to determine apparent contact; or what, under the strange effect, seemed like the phenomenon known by that name. At $3^h\ 54^m\ 45^s$ [$3^h\ 55^m\ 45^s$ in the margin, G.L.T.] it appeared to me that if *Venus* could be made round it would be just in contact with the Sun's limb.

Mr. H. A. Lenehan, First Assistant at the Sydney Observatory, observed there with an Equatoreal, by Troughton & Simms, of $4\frac{3}{4}$-inches aperture, stopped down to 4 inches, power 80. [No mention of prism or shade.]

Ingress.

"At the time of internal contact there was an indistinct shading between the supposed edge of the planet and the Sun, which, for some 10 or 15 seconds before the time I quote below, kept me in a state of uncertainty as to the true time of actual contact. The shading did not break abruptly, but seemed to melt away in such a manner as to leave a doubt in my mind of the exact time the planet passed the edge of the Sun, but I distinctly saw a clear band of light at $0^h\ 24^m\ 48^{s}{\cdot}3$.

"The *Egress* was observed under very favourable circumstances. There was a similar indistinctness between the time I mention as 'apparent contact' and 'complete contact,' as noted above at ingress. The first apparent contact was at $3^h\ 54^m\ 21^{s}{\cdot}6$, a little jumping; afterwards saw a band or narrow streak of light between the limits of the planet and Sun, which clearly showed the time given ($21^{s}{\cdot}6$) was in error. I then waited until I was *absolutely certain* contact was completed, and the time named as complete contact, $3^h\ 54^m\ 46^{s}{\cdot}6$, I feel certain is from 7 to 10 seconds too late; thinking the light might again show between [the limbs] made me feel quite certain before I noted the second time."

Dr. H. G. A. Wright observed at a station 1,950 feet south and 792 feet east of the Sydney Observatory, with an $8\frac{1}{2}$-inch Browning-With Reflector provided with one of Browning's solar eye-pieces (having two prisms arranged for single reflections), to which was added a positive eye-piece, by Ross, of 175, and a light smoke-coloured glass. The aperture was reduced to $5\frac{1}{4}$ inches. It is not stated how accurate time was obtained.

Ingress.

"The margin of *Venus*' disk continued sharply and beautifully defined as she passed on to the Sun. A slight shimmering of the solar edge might be observed at the moment when the two outlines, as it were, of the Sun and planet touched, and also some slight shading of the planet's edge (something like a penumbra), but it was clear to me that there was no 'black drop,' nor any such elongation or distortion of the black edge of *Venus* that could be taken for it. I was so intent upon observing this that I allowed some seconds to elapse before I recorded an observation of the internal contact at $0^h\ 24^m\ 30^s$. This, I have no doubt, was half a minute after actual contact, and that it was so is proved by Mr. Russell's observation at $0^h\ 23^m\ 59^s$.

Egress.

"Determined to take the most accurate observations possible of the internal contact at egress, I carefully set my chronograph by the chronometer, and was fortunately enabled to catch the precise moment of contact, at $3^h\ 54^m\ 39^s{\cdot}6$ Sydney mean time, the edge of the planet coming at that instant sharply and distinctly in contact with the Sun's limb. It was quite as clear as at ingress that there was no 'black drop.'"

Mr. F. Allerding observed at a station 1,980 feet south and 1,450 feet east of Sydney Observatory, with a telescope of $3\frac{1}{2}$-inches aperture, *stopped down with a cardboard cap to 2 inches*. It is not stated how accurate time was obtained.

"At internal contact at *ingress*, I saw a drop which formed into a cone, and when it (the cone) had nearly disappeared, it seemed to stretch out to a fine thread, to which *Venus* seemed to be attached, reaching to the Sun's limb; then the line instantaneously disappeared at $0^h\ 24^m\ 44^s$ [Sydney mean time?], but *Venus* was then already well detached from the Sun's limb. Had I not waited for the disappearance of the fine line, I would have made the internal contact *at least* 30^s *sooner*.

"I cannot be very certain about the internal contact at *egress*, having had many interruptions, but I give the time as nearly as possible at $3^h\ 54^m\ 35^s$."

Mr. L. A. Vessey observed at Woodford, N. S. W., in lat. 33° 43′ 59″ S., long. $10^h\ 1^m\ 52^s{\cdot}7$ East (Russell) with a $4\frac{3}{4}$-inch Refractor by Schroeder, stopped to 4 inches, equatoreally mounted, diagonal eye-piece; power 96, with greenish neutral glass. Time communicated by telegraph from Sydney Observatory.

"The times recorded for the internal contacts are very unsatisfactory; the observer was tired and nervous, and at Ingress the telescope was shaking in the wind.

Ingress.

	h	m	s	
Apparent internal contact estimated at	0	23	47·1	Sydney mean time.
Ingress complete some time between	0	24	39·4	and $0^h\ 24^m\ 47^s{\cdot}4$.

"The telescope was much shaken by the wind at $0^h\ 2^m\ 40^s$ and afterwards, and the ring of light around *Venus* cut through what would otherwise, I think, have been a drop, lasting 40 seconds if not a whole minute."

Egress.

"The Sun's light diminished till nothing but the silvery ring of light around the planet was left, and this ring was carried out on the sky by the slow motion of the planet.

	h	m	s	
About	3	54	25·5	or $3^h\ 54^m\ 26^s{\cdot}5$ Sydney mean time, the light between the limbs of the Sun and the planet became so thin that in the observer's estimation all direct sunlight was cut off, and nothing but the ring of light around the planet remained; or, in other words, the narrowing of the line of light between the sky and the planet then seemed to cease.
At	3	54	37·5	the cusps of the Sun's limb were distinctly separated, but connected by the fine ring of light around the planet.
At	3	54	48·4	(apparent internal contact) the circles of the Sun and planet were tangential, and the ring of light about its own thickness outside the limb of the Sun.
At	3	55	3·4	the apparent internal contact was decidedly passed, the ring now showing as an arch upon the Sun's limb.

"In my report I have unconsciously adopted the phraseology I had become accustomed to when using the artificial transit."

Professor LIVERSIDGE, of Sydney, N.S.W., University, observed at Goulburn, a town situated on the mountains, 2,300 feet above the sea,* with an Equatoreal of $3\frac{1}{4}$ inches aperture, power 150, with dark red glass screwed on to the eye-piece in the ordinary way. Time by telegraph from Sydney.

Ingress.

	h	m	s	
At	0	19	28·5	Sydney mean time, I was inclined to think that there was "apparent internal contact," as seen in the artificial transit.

* The exact position of Goulburn is not communicated. From a map of the colony it appears to be 58′ S. of Sydney and $6^m\ 28^s$ W. I have assumed it to be in lat. 34° 50′ S., long. $9^h\ 58^m\ 19^s$ E. If this position should be as much as five miles in error the equations would be very slightly affected, as Sydney mean time was telegraphed to the observers.—G. L. T.

h	m	s	
At 0	20	27·5	I again judged that there was "apparent internal contact," and considered that the former estimate was too soon.
At 0	21	29·0	the circle of *Venus* appeared to be complete and apparently just touching the Sun's limb; i.e. "internal contact" really took place.
At 0	25	1·5	the disk of *Venus* was clear of the Sun's limb, and appeared to be about one-sixteenth of the planet's diameter within it.

"During the interval between the times $0^h\,21^m\,29^s$ and $0^h\,25^m\,1^s$ a faint hazy grey filament like a streak of smoke was momentarily observed between the edge of the planet and the Sun; it was very obscure and ill defined. I unfortunately failed to note the exact time at which this cloudiness was present between the two limbs, for while trying to get it more in focus and more sharply defixed, it vanished. There did not appear to be any sudden break in it, but it faded away quite imperceptibly. No traces of the black drop were seen unless the above be considered such."

Egress.

h	m	s	
At 3	46	3·3	Sydney mean time, I fancied I could see a slight haziness between the planet and the solar limb. I do not attach any importance or value to this observation, as the haziness was exceedingly ill defined.
At 3	54	20·4	contact between the two limbs took place.
At 3	59	25·3	the planet was just beginning to pass off the Sun's limb, and it looked somewhat as if it were pushing that portion of the Sun's limb before it, for the solar limb appeared to be raised up into two processes, one on each side.

Captain Onslow, M.P., also observed at Goulburn. No mention is made of the instrument or power. Mr. Russell states that a $3\frac{3}{4}$-inch Equatoreal was sent to Goulburn, and most likely Captain Onslow and Mr. Tornaghi observed with this instrument.

Ingress.

h	m	s	
At 0	21	29·3	Sydney mean time, *Venus* apparently just touching inner edge of Sun.
At 0	23	29·3	the internal contact appeared complete, but at this moment the objects got out of my field of vision, and when again sighted, at $0^h\,25^m\,29^s{\cdot}3$, *Venus* was well inside the Sun's rim.

Mr. Tornaghi observed the *Egress* with the instrument that Captain Onslow had used at Ingress.

h	m	s	
At 3	53	44·8	Sydney mean time, the light between the edge of the Sun and the external edge of the planet was a little dim, though the circles were quite distinct.
At 3	54	25·8	time of contact. I took the time when the line of light between *Venus* and the Sun's limb disappeared.

Captain Hixson, R.N., President of the Marine Board, also observed at Goulburn, with a 6-inch Equatoreal, power 130.

Egress.

h m s
At 3 54 28·0 I judged that contact took place. Previous to this there was a portion of light visible between the planet and the Sun.

*** It should be stated that none of the telescopes used at Goulburn were provided with proper means for observing the Sun. The Sun was near the zenith at Ingress, the thermometer in the shade stood at 104° Fah. All Captain Hixson's dark glasses split, causing him to lose the Ingress entirely.—G. L. T.

The Rev. W. Scott observed at Eden, N. S. W., latitude 37° 3′ 47″ S., longitude $9^h\ 59^m\ 36^s{\cdot}25$ E. (Russell), with $7\frac{1}{2}$-inch Equatoreal; power and shade not stated. Time was communicated by telegraph from Sydney Observatory. *The aperture was reduced to 2 inches.*

Ingress.

"I saw the partial obscuration of the Sun's limb by the planet's atmosphere gradually diminishing until it disappeared altogether at $0^h\ 24^m\ 48^s$ Sydney mean time."

Mr. McDonnell observed at the same place with $4\frac{1}{4}$-inch Equatoreal by T. Cooke & Sons; power 98, diagonal reflector and light bluish glass.

h m s
At 0 19 24·0 Sydney mean time, apparent contact was noted. As *Venus* proceeded the shadowy envelope disappeared, except between the planet and the Sun's limb, where it seemed to fill up the space between them with faint rings concentric with the planet's edge. There was no distinct rupture of this appearance, the light seeming to go in and out several times and prevented any accurate notation of the complete ingress. I
0 25 14·7 marked $0^h\ 25^m\ 14^s{\cdot}7$ as the time, but feel now convinced that it took place at least 15^s earlier. There was no abrupt breaking of the "ligament," if it can be so called, but a gradual dissolving away.

The *Egress* was lost through clouds.

Mr. John Tebbutt, at his private Observatory, Windsor, N. S. W., lat. 33° 36′ 30″ S., long. $10^h\ 3^m\ 15^s{\cdot}7$ E. (*Nautical Almanac*) observed with an Equatoreal of $4\frac{1}{2}$ inches aperture (not reduced), diagonal prism, negative eye-piece of 120. The lens next the prism was smoked, a neutral tint glass, also smoked, was secured to the eye end of the eye-piece, and, in addition, another glass of very light neutral tint was occasionally employed. By this combination the Sun's limb appeared of a straw colour and the sky intensely black.

Ingress.

"* * * A few seconds afterwards it was obvious that the apparent contact had taken place, the planet's limb being seen slightly within that of the Sun, but connected with it by a dusky ligament, whose breadth was about one-fourth the diameter of the planet. Instead, however, of the solar cusps being squared off by this ligament, they were rounded, the convexity being towards the ligament. In other words, the ligament was contracted in the middle. It was of a lighter shade across the middle between the rounded ends of the cusps than it was along the limbs of the Sun and planet. The more deeply shaded portion of this ligament resembled in colour the limb of the Moon when entering the Earth's dark shadow during eclipse. The distance between the limbs of the Sun and planet—for the solar limb at the point of contact could be faintly seen—did not at this time exceed a second of arc. During two or three beats of the half-seconds chronometer I noticed that the ligament was affected with a vibratory or tremulous motion in the direction of the line joining the centre of *Venus* with the point of contact. At the same time it resolved itself into several dusky streaks parallel to the limb of the Sun. These were at once quickly absorbed, partly into the black disk of *Venus* and partly into the dark margin of sky along the Sun's limb. The planet was then seen slightly within the solar limb, with the space between the two limbs as bright as the other portion of the Sun's disk. The disappearance of the dusky streaks, which phenomenon I regard as the real internal contact, occurred at $0^h\ 22^m\ 54^s{\cdot}8$ local mean time.

"The *Egress* was watched without the light neutral tint glass already mentioned. The images at *Ingress* were steady, but I think the definition at *Egress* was somewhat better. When the planet's preceding or western limb was within a second or so of reaching the Sun's limb, I noticed that the thread of light between the limbs almost suddenly became shaded by a ligament resembling that observed at Ingress, its breadth being also about one-fourth of the diameter of the planet. The formation of this ligament occurred at $3^h\ 53^m\ 0^s{\cdot}3$ local mean time. The observation was excellent, and the counting of the chronometer half-seconds was verified in the usual way. The Sun's limb was only faintly perceptible. Immediately following the above recorded time in the original notes of my observations are the entries $3^h\ 53^m\ 14^s{\cdot}8$ and $3^h\ 54^m\ 6^s{\cdot}3$ as corrected for the error of the chronometer. What these times represent I cannot now say, as the appropriate or corresponding phases are not stated, but it is probable that the first was an attempt to fix the instant of apparent coincidence of limb, and the second an attempt to estimate the time corresponding to some distance between the cusps of the Sun."

Mr. Charles Todd, at the Adelaide Observatory, latitude 34° 55′ 33″ S., longitude $9^h\ 14^m\ 21^s{\cdot}3$ E.,* observed with the 8-inch Refractor by T. Cooke & Sons, the aperture being reduced to 4 inches. The double [filar] micrometer eye-piece, with a [Ramsden] power of 140, was used throughout.

The Ingress was lost through cloud.

Egress.—"With regard to the 'black drop' of which so much has been written, I wish I had never heard of it, as looking eagerly for its appearance and not seeing what I expected was certainly calculated to bias my judgment as to the precise instant of internal contact. As the planet closed up to the Sun's limb it seemed to be but very slightly, perhaps a little, disturbed; but I saw nothing like the representations of the 'black drop.' There was, I thought, a slight oscillatory movement (of course only apparent) of the planet to and from the limb, which made it excessively difficult to fix positively the exact instant of contact, neither the Sun's limb nor the planet being sharply defined, but the time first noted by me—viz. $3^h\ 4^m\ 42^s{\cdot}1$ local mean time—was when I thought the continuity of the Sun's limb, or the fine streak of light, appeared to be broken, although the planet did not appear to be quite in contact, but rather seemed to be connected with the Sun's limb by a most minute protuberance or fine filament, too small to be shown in any drawing. At $3^h\ 4^m\ 54^s{\cdot}5$ the contact seemed to be full or tangential. Perhaps the true instant lies between the two times noted. I can hardly say to which I would attach the greater weight."

Mr. F. C. Singleton observed with a 3-inch Achromatic mounted in the Observatory grounds. Internal contact, $3^h\ 4^m\ 41^s$ Adelaide mean time.

Mr. J. D. Smeaton, J.P., observed at his residence, 136 chains north and 86 chains east of the Observatory, with an excellent Equatoreal of $3\frac{1}{2}$ inches by Cooke & Sons.

Internal contact at $3^h\ 5^m\ 5^s$ Adelaide mean time. No black drop, the osculation being perfect and the cusps of light between the Sun and planet quite sharp.

Mr. A. W. Dobbie observed with an $8\frac{1}{2}$-inch silvered glass Reflector at his residence, about 880 yards north and 3·740 yards† east of the Observatory, his watch being compared with the transit clock at the Observatory. Internal contact at Egress, $3^h\ 5^m\ 6^s$ A.M.T.

Mr. Todd, who communicates these last three observations, adds: "I think it well to give you these outside observations, although, from the uncertainty in the determination of time, they may not be of great value."

* It is not stated on what the longitude depends.

† So in the original, not 3,740.

Mr. D. Flitner observed the *Ingress* at Waikiki, near Honolulu, with an Achromatic of $2\frac{1}{4}$ or $2\frac{1}{2}$ inches aperture, power 80–100. He recorded the "internal contact complete, and full sunlight between the planet and the Sun's limb," at $3^h\ 36^m\ 8^s{\cdot}4$ local mean time [$=7^h\ 18^m\ 4^s{\cdot}3$ Gr. sid. time]. Lat. 21° 16′ 0″ N., long. $10^h\ 31^m\ 19^s{\cdot}3$ W. (Tupman). His chronometer was compared with the Honolulu transit clock.

Don F. Diaz Covarrubias* observed at Nogue-no-yama, Japan, lat. 35° 26′ 54″·2 N., long. $9^h\ 18^m\ 34^s$ E., in the following manner:—A zenith telescope of $2\frac{3}{4}$ inches aperture, with its filar micrometer eye-piece, was made to produce an image of the Sun, $4\frac{3}{4}$ inches in diameter, upon a sheet of paper painted a light grey colour, the observer using a lens to view the image so produced.

"In regard to the internal contacts, the presence of the black ligament rendered it almost impossible to appreciate the exact instant of geometrical contact."

Ingress.

	h	m	s	
Internal geometrical contact	23	29	24·6	Local mean time.
Rupture of the ligament	23	30	25·6	„ „

Egress.

	h	m	s	
Formation of the ligament	3	21	1·4	„ „
Internal geometrical contact	3	21	45·4	„ „

"I had hoped that this manner of observing would prevent the ligaments being seen; but, unfortunately, and notwithstanding the precision of the images, they were seen in a very marked manner. Not only were they seen, but the rupture at the first internal contact and the formation at the second, far from being instantaneous, took place by almost insensible gradations of the light, which necessarily caused some doubt as to the exact moments of disappearance and appearance. Equal or even greater uncertainty attended the estimation of the internal geometrical contacts, as is easily understood bearing in mind the extreme slowness with which the planet crossed the Sun's disk."

Don F. Jimenez, observing at Bluff, lat. 35° 26′ 16″·6 N., long. $9^h\ 18^m\ 39^s$ E., in precisely the same manner, the only difference being that his zenith telescope was $3\frac{3}{4}$ inches aperture, records:—

* *Observaciones del Tránsito de Vénus hechas en el Japon.* Paris, 1875. The longitude depends upon 14 Moon culminations.

Ingress.

	h	m	s	
Internal geometrical contact	23	29	50·0	Local mean time.
Rupture of the ligament	23	30	43·5	,, ,,

Egress.

	h	m	s	
Formation of the ligament	3	21	20·9	Local mean time.
Internal geometrical contact	3	21	50·9	,, ,,

Discussion of the Observations.

The theory that the method of durations offers much greater precision in the determination of the solar parallax than that of the comparison of similar phases is founded entirely upon the supposition that the errors of observation of the times of contact are much less than the probable errors of the longitudes employed. No one will now deny that the reverse is the actual case. The errors of the longitudes here used can rarely amount to 5 seconds of time, and it is probable that nearly the whole of them are correct within 2^s or 3^s; whereas the difficulty of observing the internal contacts was such that observers side by side, with adequate optical means, differed as much as 20^s or 30^s in the times they recorded for phenomena which they have described in almost identical language. Errors of observation such as these affect the two methods equally when the parallactic conditions are equal.

It is evident, then, that the method of comparison of similar phases offers great advantages. It enables a very much larger number of observations to be employed, generally under more favourable parallactic conditions, and from the fact that the *Ingress* and *Egress* are entirely independent of each other, two strictly independent results are obtained, the agreement or disagreement of which will, in a great measure, influence the value to be attributed to them.

The parallax deducible from these observations depends, within certain not very narrow limits, upon the selection of the times corresponding to the phase under discussion. In many cases there is no choice—the observers have simply recorded "contact" at a definite instant. In others there will be no two opinions as to the proper times to select; while for the remainder, not a large proportion of the whole, the selection is a matter of judgment. The most important case open to dispute is that of the observations in the Sandwich Islands, where several observers recorded very late times, in my opinion merely to notify that all was over.

The Ingress.

The most satisfactory way perhaps to treat the *Ingress* is to rely upon the observation of the brightening or clearing of the

dusky light seen by all observers between the limbs after the circular form of the Sun's limb was restored. With some of the smaller instruments, no doubt in some degree depending upon the colour and intensity of the absorbing media employed, this brightening occupied a very long time, but generally in the larger instruments the uncertainty was confined to less than 10^s. If a model, artificially representing as nearly as possible the circumstances of the transit, be set in the proper position for 10^s after internal contact at Ingress, a kind of shadow will be visible between the limbs when the attention is not strictly confined to the point of contact. This may perhaps explain some of the very late times recorded for Ingress complete, and the very early ones for beginning of Egress.

The following, then, are the times which I select, and the equations of condition founded on them, derived from the formulæ in the Astronomer Royal's Paper in the *Monthly Notices* for 1875, March. The symbol i is a constant for Ingress, common to all stations, compounded of the corrections required to the tabular semidiameters, the true distance between the limbs at the moment assumed as contact, and the effect of the imperfect corrections of the Tabular R.A. and N.P.D. These corrections have been assumed to be $+5''{\cdot}81$ and $-5''{\cdot}33$ respectively. The correction required to the tabular mean solar equatoreal horizontal parallax ($8''{\cdot}950$) is $8''{\cdot}950\left(1+\frac{n}{100}\right)$. The coefficient of dt is the variation of the distance of centres in one sidereal second, computed for the centre of the Earth, but sufficiently accurate for the surface.

Internal Contact at Ingress.

Observer.	Recorded Time. h	m	s	Local Tabular Distance of Centres. ′	″	Resulting Equation.	Weight.
Cator	1	20	29	15	37·47	$i+{\cdot}2284\,n+{\cdot}0343\,dt=-{\cdot}388$	0
Noble	20	46	2	15	37·54	$i+{\cdot}2284\,n+{\cdot}0342\,dt=-{\cdot}318$	1
Tupman	20	46	20	15	37·58	$i+{\cdot}2284\,n+{\cdot}0344\,dt=-{\cdot}278$	2
Flitner	3	36	8·4	15	37·47	$i+{\cdot}2283\,n+{\cdot}0343\,dt=-{\cdot}388$	1
Johnson	20	46	57·6	15	37·51	$i+{\cdot}2280\,n+{\cdot}0340\,dt=-{\cdot}348$	2
Dunn	3	39	1·2	15	36·86	$i+{\cdot}2279\,n+{\cdot}0343\,dt=-{\cdot}997$	0
Diaz	23	30	25·6	15	37·77	$i+{\cdot}1325\,n+{\cdot}0360\,dt=-{\cdot}087$	1
Jimenez	23	30	43·5	15	37·28	$i+{\cdot}1328\,n+{\cdot}0352\,dt=-{\cdot}576$	1
Palmer	18	58	52	15	38·075	$i-{\cdot}0142\,n+{\cdot}0318\,dt=+{\cdot}205$	1
Russell	0	24	14	15	37·85	$i-{\cdot}0173\,n+{\cdot}0312\,dt=-{\cdot}018$	2
Wright	0	24	30	15	37·32	$i-{\cdot}0172\,n+{\cdot}0315\,dt=-{\cdot}542$	0
Lenehan	0	24	33	15	37·21	$i-{\cdot}0170\,n+{\cdot}0321\,dt=-{\cdot}657$	0
Allerding	0	24	14	15	37·85	$i-{\cdot}0173\,n+{\cdot}0312\,dt=-{\cdot}018$	0
Tebbutt	0	22	54·8	15	37·43	$i-{\cdot}0172\,n+{\cdot}0321\,dt=-{\cdot}438$	2

Observer.	Recorded Time. h	m	s	Local Tabular Distance of Centres. ′	″	Resulting Equation.	Weight.
Vessey	0	24	43·4	15	36·98	$i - ·0182\,n + ·0321\,dt = -·888$	0
Liversidge	0	25	1·5	15	36·97	$i - ·0238\,n + ·0305\,dt = -·896$	0
Tennant	12	42	30	15	37·25	$i - ·0295\,n + ·0324\,dt = -·609$	0
Scott	0	24	47·9	15	38·07	$i - ·0305\,n + ·0320\,dt = +·204$	2
McDonnell	0	25	0	15	37·68	$i - ·0305\,n + ·0305\,dt = +·012$	1
Gilbert	0	0	42·5	15	37·19	$i - ·0366\,n + ·0319\,dt = -·678$	0
Morris	0	0	45·8	15	37·08	$i - ·0366\,n + ·0319\,dt = -·788$	0
Bigg-Wither	12	17	8·	15	37·87	$i - ·0403\,n + ·0324\,dt = +·011$	1
Ellery	0	0	44·8	15	37·82	$i - ·0436\,n + ·0319\,dt = -·050$	2
White	0	0	44·0	15	37·84	$i - ·0436\,n + ·0319\,dt = -·030$	1
Wilson	0	0	39·5	15	38·10	$i - ·0448\,n + ·0319\,dt = +·230$	1
Neate	11	52	14·8	15	38·00	$i - ·1937\,n + ·0306\,dt = +·123$	2
Wharton	9	57	3	15	37·875	$i - ·1935\,n + ·0312\,dt = -·001$	1
Hoggan	6	36	32·8	15	37·35	$i - ·1935\,n + ·0296\,dt = -·526$	0
Corbet	12	20	8·	15	38·295	$i - ·2153\,n + ·0294\,dt = +·409$	2
Coke	8	43	46·5	15	37·81	$i - ·2152\,n + ·0287\,dt = -·076$	1
Goodridge	7	9	46·7	15	37·935	$i - ·2146\,n + ·0288\,dt = +·049$	1

The solution of these equations by the method of least squares, putting $dt = 0$ and giving them for the present equal weights, is

$$i = -0''·271$$

$$n = -0·975,$$

whence the mean solar parallax $= 8''·863$.

Substituting these values in the equations, we obtain the following values of dt in seconds of time, the sign + indicating that the observation as interpreted by me was too early :—

	s		s		s
Cator	+ 3·1	Lenehan	−12·6	Ellery	+ 5·6
Noble	+ 5·2	Allerding	+ 7·6	White	+ 6·2
Tupman	+ 6·3	Tebbutt	− 5·8	Wilson	+14·3
Flitner	+ 3·1	Vessey	−19·8	Neate	+ 6·7
Johnson	+ 4·3	Liversidge	−21·2	Wharton	+ 2·6
Dunn	−14·7	Tennant	−11·3	Hoggan	−15·0
Diaz	+ 8·7	Scott	+13·9	Corbet	+16·0
Jimenez	− 5·0	McDonnell	+ 8·3	Coke	− 0·5
Palmer	+14·5	Gilbert	−13·9	Goodridge	+ 3·9
Russell	+ 7·6	Morris	−17·3		
Wright	− 9·1	Bigg-Wither	+ 7·5		

In order to derive the most satisfactory result, however, some system of weighting is indispensable. It is obviously absurd to give equal weights to observations made by experienced observers, with powerful optical means under favourable atmospheric conditions, and to those made under conditions more or less the reverse. Cator used a very low power, he gives no description of the phenomena observed, and his sketches were made afterwards from memory; Dunn is 20^s behind five other observers near him, his telescope was small and much shaken by the wind; Wright, Lenehan, and Allerding acknowledge their observations to be very unsatisfactory, they all waited much too long; Vessey, Liversidge, Gilbert, and Morris are between 20 and 30 seconds behind the average of eleven others in the same district; Tennant's time is very late, probably from the circumstance of the double-image micrometer eye-piece having been employed; and in Hoggan's case the subjective phenomena were exaggerated by the brightness of the image, which was insufficiently toned down.

I think these observations are not comparable with the mass of the others, and that their introduction slightly vitiates the result. I have therefore rejected them in the final discussion. Considering the optical means and the favourable atmospheric conditions, it seems fair to give the double weights shown in the column. There is a difference of 16^s between Corbet and Coke, who were side by side, and it is evident that Coke was late. I have given double weight to Corbet's observation.

There are now twenty observations left, eight of which have double weight, and the solution of the equations derived from them is:—

$$i = -1''.071$$
$$n = -0''.177,$$

whence the mean solar parallax is $8''.845$.

Substituting, as before, we have the residuals:—

	s		s		s
Noble	+ 0·6	Russell	+ 1·1	Wilson	+ 7·8
Tupman	+ 1·9	Tebbutt	−12·1	Neate	− 1·1
Flitner	− 1·4	Scott	+ 7·5	Wharton	− 5·1
Johnson	− 2·4	McDonnell	+ 1·5	Corbet	+ 7·7
Diaz	+ 3·9	Bigg-Wither	+ 1·1	Coke	− 9·0
Jimenez	− 9·9	Ellery	− 1·0	Goodridge	− 4·6
Palmer	+ 8·1	White	− 0·9		

The errors of the rejected observations now appear to be:—

	s		s		s
Cator	− 1·4	Allerding	+ 1·1	Gilbert	−20·4
Dunn	−19·2	Vessey	−26·1	Morris	−23·8
Wright	−15·6	Liversidge	−27·9	Hoggan	−23·1
Lenehan	−18·9	Tennant	−17·7		

The Egress.

It is very interesting, as illustrating the difficulty, or rather the unsatisfactory nature of the observation, and the small value that can be attributed to any recorded time, to compare the observations of Campbell, Tennant, Copeland, Gill, Russell, and Todd, on the one hand, with those of Ellery, Hunter, Mrs. Campbell, and Orde Browne, on the other. The former see little or nothing to interfere with an observation of tolerably definite contact; the latter have disturbing phenomena extending over various intervals, in Mr. Ellery's case to $2\frac{1}{2}$ *minutes* of time. Again, Captains Bigg-Wither and Strahan, at different stations, declare there was no contact at all; *Venus pushed the Sun's limb out before her.*

The following are the times which I consider should be selected for the critical phase of egress, and the equations deduced from them:—

Internal Contact at Egress.

Observer.	Recorded Time.			Local Tabular Distance of Centres.		Resulting Equation.	Weight.
	h	m	s	′	″		
Wilson	3	29	31·4	15	42·01	$e - \cdot1313\,n - \cdot0328\,dt = + \cdot516$	1
Ellery	3	29	20·	15	41·49	$e - \cdot1297\,n - \cdot0317\,dt = - \cdot001$	2
White	3	29	15·	15	41·34	$e - \cdot1297\,n - \cdot0317\,dt = - \cdot149$	1
Liversidge	3	54	20·4	15	41·52	$e - \cdot1278\,n - \cdot0329\,dt = + \cdot015$	1
Tornaghi	3	54	25·8	15	41·69	$e - \cdot1278\,n - \cdot0329\,dt = + \cdot183$	1
Hixson	3	54	28·0	15	41·76	$e - \cdot1278\,n - \cdot0329\,dt = + \cdot252$	1
Russell	3	54	39·7	15	42·09	$e - \cdot1276\,n - \cdot0318\,dt = + \cdot573$	2
Lenehan	3	54	36·6	15	41·99	$e - \cdot1276\,n - \cdot0318\,dt = + \cdot473$	1
Wright	3	54	39·6	15	42·09	$e - \cdot1276\,n - \cdot0318\,dt = + \cdot573$	1
Allerding	3	54	35·	15	41·93	$e - \cdot1274\,n - \cdot0318\,dt = + \cdot415$	1
Moerlin	3	29	36·6	15	41·63	$e - \cdot1258\,n - \cdot0328\,dt = + \cdot130$	1
Tebbutt	3	53	0·3	15	41·67	$e - \cdot1259\,n - \cdot0330\,dt = + \cdot156$	2
Vessey	3	54	26·0	15	41·48	$e - \cdot1257\,n - \cdot0329\,dt = - \cdot031$	2
Todd	3	4	48·3	15	41·625	$e - \cdot1115\,n - \cdot0320\,dt = + \cdot103$	2
Singleton	3	4	41·	15	41·39	$e - \cdot1115\,n - \cdot0317\,dt = - \cdot122$	1
Smeaton	3	5	5·	15	42·18	$e - \cdot1118\,n - \cdot0331\,dt = + \cdot668$	0
Dobbie	3	5	6·	15	42·21	$e - \cdot1118\,n - \cdot0331\,dt = + \cdot698$	0
Goodridge	10	30	24·0	15	41·03	$e - \cdot1010\,n - \cdot0317\,dt = - \cdot346$	1
Sidgreaves	10	27	42·8	15	41·135	$e - \cdot1006\,n - \cdot0317\,dt = - \cdot243$	1
Perry	15	40	38·8	15	41·69	$e - \cdot1004\,n - \cdot0309\,dt = + \cdot306$	1
Finlay	19	7	11·0	15	41·63	$e - \cdot0590\,n - \cdot0314\,dt = + \cdot278$	1
Stone	19	7	12·0	15	41·66	$e - \cdot0590\,n - \cdot0314\,dt = + \cdot308$	2

Observer.	Recorded Time. h	m	s	Local Tabular Distance of Centres. ′	″	Resulting Equation.	Weight.
Spindler	19	7	25·0	15	41·50	$e - ·0525\,n - ·0315\,dt = + ·031$	1
Hoggan	10	4	53·5	15	41·45	$e + ·0271\,n - ·0332\,dt = - ·086$	1
Neate	15	21	27·2	15	41·27	$e + ·0274\,n - ·0322\,dt = - ·263$	2
Wharton	1	25	48·1	15	41·62	$e + ·0275\,n - ·0320\,dt = + ·085$	1
Copeland	21	48	11·3	15	41·21	$e + ·0296\,n - ·0331\,dt = - ·313$	2
Gill	21	48	12·5	15	41·26	$e + ·0296\,n - ·0331\,dt = - ·264$	2
Diaz	3	21	1·4	15	41·39	$e + ·1265\,n - ·0352\,dt = - ·474$	1
Jimenez	3	21	20·9	15	41·93	$e + ·1260\,n - ·0350\,dt = + ·060$	1
Miss Pogson	23	24	32·	15	41·95	$e + ·1453\,n - ·0343\,dt = + ·191$	1
Chary	23	24	46·	15	42·43	$e + ·1453\,n - ·0343\,dt = + ·666$	0
Pillay	23	25	12·	15	43·31	$e + ·1452\,n - ·0353\,dt = + 1·535$	0
N. Row	16	47	15·4	15	38·48	$e + ·1579\,n - ·0340\,dt = - 3·255$	0
Addison	15	44	10·9	15	40·52	$e + ·1905\,n - ·0353\,dt = - 1·248$	0
Ommanney*	20	1	2·5	15	41·54	$e + ·1908\,n - ·0338\,dt = - ·166$	1
Mrs. Campbell*	6	14	57·5	15	41·55	$e + ·1908\,n - ·0338\,dt = - ·156$	1
Auwers*	18	57	58·	15	41·62	$e + ·1908\,n - ·0338\,dt = - ·087$	2
Col. Campbell*	6	6	31·	15	41·62	$e + ·1908\,n - ·0338\,dt = - ·087$	2
Döllen*	13	29	16·5	15	41·84	$e + ·1908\,n - ·0338\,dt = + ·133$	1
Tennant	16	28	36·1	15	41·55	$e + ·1959\,n - ·0364\,dt = - ·277$	2
Hennessey	18	5	32·6	15	40·83	$e + ·1973\,n - ·0350\,dt = - ·984$	0
Hunter	13	27	19·	15	41·61	$e + ·2021\,n - ·0340\,dt = - ·117$	2
Newton	13	22	20·7	15	41·34	$e + ·2016\,n - ·0339\,dt = - ·381$	1
Miss Newton	8	10	35·0	15	41·41	$e + ·2016\,n - ·0339\,dt = - ·312$	1
Browne	13	22	25·0	15	41·44	$e + ·2016\,n - ·0339\,dt = - ·278$	2
Mahmoud Bey	20	11	13·2	15	41·52	$e + ·2017\,n - ·0342\,dt = - ·204$	1
Strahan	16	14	36·9	15	41·30	$e + ·2026\,n - ·0365\,dt = - ·525$	1

I think it advisable to reject the observations of Smeaton and Dobbie, as no one guarantees the correctness of the local time. At Madras the Sun was barely visible through the clouds: perhaps none of the observations there should have been used. I have, however, retained the one which appeared to agree pretty well with the average. General Addison's observation being 30^s, Mr. Hennessey's 22^s, and Mr. Nursinga Row's a minute and a half earlier than the average, are also not included. None of them contain details by which the phase observed can be identified.

* The times of the Luxor observers have been taken from Dr. Auwers' *Bericht über die Beobachtung des Venus-Durchgangs vom* 8 *Dec.* 1874. Berlin, 1878.

I have given double weight to some observers as at *Ingress*. The solution of these equations thus weighted is:

$$e = +0''.007$$
$$n = -1''.157,$$

whence the mean solar parallax is $8''.846$.

The following are the residuals from this solution, the sign + indicating, as before, that the observation as interpreted by me was too early:—

	s		s		s
Wilson	−10·9	Singleton	+ 8·1	Miss Pogson	−10·3
Ellery	+ 5·0	Goodridge	+14·8	Ommanney	− 1·4
White	+ 9·7	Sidgreaves	+11·6	Mrs. Campbell	− 1·7
Liversidge	+ 4·3	Perry	− 5·9	Auwers	− 3·7
Tornaghi	− 0·9	Finlay	− 6·5	Campbell	− 3·8
Hixson	− 3·0	Stone	− 7·4	Döllen	−10·3
Russell	−13·1	Spindler	+ 1·1	Tennant	+ 1·6
Lenehan	−10·0	Hoggan	+ 1·9	Hunter	− 3·3
Wright	−13·1	Neate	+ 7·4	Newton	+ 4·6
Allerding	− 8·2	Wharton	− 4·7	Miss Newton	+ 2·5
Moerlin	+ 0·7	Copeland	+ 8·7	Browne	+ 1·5
Tebbutt	− 0·1	Gill	+ 7·2	MahmoudBey	− 0·7
Vessey	+ 5·6	Diaz	+ 9·5	Strahan	+ 8·2
Todd	+ 1·0	Jimenez	− 5·7		

The errors of the rejected observations appear to be:

	s		s		s
Smeaton	−16·1	Pillay	−48·0	Addison	+29·3
Dobbie	−17·0	N. Row	+90·6	Hennessey	+21·8
Chary	−24·0				

Looking at the residuals from this solution of the Egress, it is seen that the observations at Sydney, N. S. W., viz. by Russell, Lenehan, Wright, and Allerding, have great weight in lowering the value of the parallax, and this effect is aggravated by allowing Russell double weight, by Wilson's late observation at Mornington, and by the early observations of Diaz and Strahan at stations where the Egress was retarded. The extreme observations tending in the opposite direction, or to increase the parallax, have very far from an equal effect. These are the early times of White, Singleton, Goodridge, and Sidgreaves, and the late times of Miss Pogson and Döllen.

The adopted longitude of Sydney is probably not 3^s in error, and cannot have much to do with the late times observed there. Mr. Russell's is one of the most detailed observations made; it seems impossible, from his description, to choose his earlier time. Mr. Lenehan admits he was late, and I have taken 10^s from his

time, but still it is late. Dr. Wright made "the most accurate observation possible," and agrees to a fraction of a second with Mr. Russell. Mr. Allerding does not profess to have made a good observation.

Captain Strahan's is an early observation by the wording, but so also are those of Moerlin, Stone, and Finlay, although every solution makes the two last named a few seconds *late*. Professor Wilson's is perhaps not an observation at all.

Out of mere curiosity I have solved the 35 equations that remain, when Wilson's, Strahan's, and those at Sydney are excluded, retaining the same weights as before, and find

$$e = -0''.059$$
$$n = -0''.626,$$

whence the mean solar parallax is $8''.894$.

From this solution we have the following residuals:—

	s		s		s
Ellery	+ 0·7	Perry	− 9·8	Ommanney	− 0·4
White	+ 5·4	Finlay	− 9·6	Mrs. Campbell	− 0·7
Liversidge	+ 0·2	Stone	−10·5	Auwers	− 2·7
Tornaghi	− 4·9	Spindler	− 1·8	Campbell	− 2·7
Hixson	− 7·0	Hoggan	+ 0·3	Döllen	− 9·2
Moerlin	− 3·4	Neate	+ 5·8	Tennant	+ 2·6
Tebbutt	− 4·1	Wharton	− 5·0	Hunter	− 2·0
Vessey	+ 1·6	Copeland	+ 7·1	Newton	+ 5·8
Todd	− 2·9	Gill	+ 5·6	Miss Newton	+ 3·8
Singleton	+ 4·2	Diaz	+ 9·5	Browne	+ 2·8
Goodridge	+11·0	Jimenez	− 5·7	MahmoudBey	+ 0·6
Sidgreaves	+ 7·8	Miss Pogson	−10·0		

and the apparent errors of the others are:—

	s		s		s
Wilson	−15·0	Smeaton	−19·9	Addison	+30·3
Russell	−17·3	Dobbie	−20·8	Hennessey	+22·9
Lenehan	−14·2	Chary	−23·8	Strahan	+ 9·3
Wright	−17·3	Pillay	−47·7		
Allerding	−12·4	N. Row	+91·1		

This solution certainly satisfies very well a large majority of the observations, but it makes the Cape times appear 10^s and the Sydney 17^s late. Such a parallax as $8''.89$ therefore appears improbable. On the other hand, if the extreme observations of Egress which tend to a large parallax be rejected—such as those of White, Goodridge, Sidgreaves, Miss Pogson, and Döllen, three of which were greatly interfered with, if not entirely spoiled, by clouds—a result as small as $8''.79$ would be obtained.

Although the above results of Ingress and Egress present such an unexpected agreement, it cannot be said that the mean 8″·8455 is entitled to much confidence, since all the observations would be fairly well satisfied by any mean solar parallax between 8″·82 and 8″·88. 8″·8455 corresponds to a mean distance of the Sun of 92,400,000 British statute miles.

Remarks on former Papers on the same Subject.

The Astronomer Royal's "Parliamentary Report," which was brought out somewhat hurriedly under pressure, contained the first discussion of detailed observations. As far as concerns the Ingress that report included all the more important observations—that is, those from which the Parallax is more directly determined. The treatment assumed that certain phases called α, β, γ, &c., separated some 20^s from one another, were recognised at every station, in spite of the very different language employed. The phases were all cast and criticised before any calculation of the parallax was made, and therefore the result was a perfectly legitimate deduction, not open to any suspicion of having been "doctored," which is more than can be said of later results. Mr. Stone has pointed out, and I have no doubt he is right, that the phases were incorrectly cast for the Sandwich Islands' observations, and consequently a systematic error was introduced. It is still a matter of opinion whether this is so. Mr. Christie and Mr. Gill have independently cast the phases, being guided only by the observers' language, and they arrive substantially at the cast adopted in the report, and therefore at a very small parallax (about 8″·74) from Ingress.

In the *Monthly Notices*, vol. xxxviii., p. 279, Mr. Stone has discussed these observations, disregarding the supposed phases, and depending upon the critical phase of "Ingress complete." He arrives at the parallax 8″·860±·04, giving all observers equal weight, including Cator and Hoggan. Mr. Stone considers that Corbet was too early, and favours the mean of Coke and Goodridge; but I must say I think Corbet's probably the best observation, and that the other two were late. Corbet's language is decisive that the shadow had disappeared at his last recorded time. The general tendency of the observation was to be late—everybody was late, but in different degrees.

The discussion of the Egress in the Parliamentary Report is perfectly satisfactory. The critical phase ζ gives a parallax of 8″·90. By allowing the earlier phases some weight the value of the parallax was reduced to 8″·85. Mr. Stone deduces the values 9″·04, 9″·06, and 8″·98±·08; but in view of the large number of observations of Egress now available, it is useless to discuss further the British observations *per se*.

In the *Monthly Notices*, vol. xxxviii., p. 11, the Astronomer Royal communicates a general solution of the equations of condition derived from the phases adopted in the Parliamentary Report. The parallax deduced is, of course, the same as that of the Report.

The next paper appears as a portion of the Report of the Council published in February last (page 198). The former result of Ingress (8″·74) is accepted, and is combined with a new Egress result (8″·77) depending upon the phase ζ as supposed to be identified in all the available observations. Here again the attempt to fasten these phases, δ, ϵ, ζ, and η, as originally defined, upon everybody's observations led to very erroneous results. For instance, in the case of the Cape observations (as originally communicated) there was no alternative but to cast Mr. Stone's $19^h\ 7^m\ 12^s$ and Mr. Finlay's $19^h\ 7^m\ 11^s$ as δ. The language employed in describing the phase corresponding to the time is in both instances the very definition of δ, viz. "the first appearance of shadow between the limbs." δ appearing to be safely cast, ζ was found by taking the mean of Mr. Stone's two later times, which seemed supported by Mr. Maclear's only time, $19^h\ 7^m\ 48^s$; and thus a time for phase ζ was arrived at which was at least 36^s too late, as shown by subsequent calculation; but it was impossible to know this until the calculation had been made. As instances of how little the observer's language can be depended on in selecting similar phases, the earliest recorded times of Moerlin, Stone, Finlay, Vessey, and Tebbutt—and especially remarkable is the language of the two first named as indicating extremely early phases—are undoubtedly identical with the very last recorded times of Spindler, Mrs. Campbell, and Hunter, with late times of Ellery, White, and Browne, and also, very curiously, with the apparently very late time of Perry at Kerguelen's, who was 36^s later than Goodridge's first detection of shadow; 22^s later than the same observer's time for a black drop "as black as the planet"; and 18^s later than Sidgreaves' "circular contact."

In commencing an investigation of the parallax from these and similar observations, some selection of phases, depending on the observer's language and on the mutual agreement of observers not very far apart, must be made. Any selection of times made *after an investigation of the effects of parallax*, such as that I have now made, will always expose the result to the suspicion of having been "doctored."

The conclusion being inevitable that the numerous observations of the Transit of 1874, made with modern instruments of great power and excellence, only enable us to determine that the solar parallax probably lies between the values 8″·82 and 8″·88, we naturally suspect that the value obtained from comparatively few observations made more than one hundred years ago with very inferior means cannot, in the abstract, be deserving of much confidence. Indeed, Encke deduced the parallax 8″·60, and Stone 8″·91, from the observations of the Transit of 1769. The parallax obtained chiefly depends upon the observations of Green and Cook at Otaheite, who are very discordant in their recorded times; and we may be sure, from their descriptions of the appearance of the planet upon the Sun, that their instruments—reflectors of only 24 inches focal length, and unfortunately both alike—

would nowadays be considered worthless. The probable error of their contacts, instead of being 3^s, as Mr. Stone thought nine or ten years ago, was more likely 20^s or 30^s. I consider that the observations of the Transit of 1769 are fairly satisfied, taking into account the instruments used and the errors actually committed in 1874, by any parallax between $8''{\cdot}60$ and $8''{\cdot}95$. The equations given by Mr. Stone (*Monthly Notices*, vol. xxviii., p. 263) enable anyone with great facility to find the effect of "doctoring" the times of duration.

On some Terms of Long Period in the Mean Motion of Mars.
By E. Neison.

I have lately discovered two new terms of long period in the mean motion of the planet *Mars* which have coefficients of sensible value, and whose existence will in part explain the present errors in Leverrier's Tables of *Mars*. These terms are due to the second power of the disturbing forces, and arise in the main from the action of one planet on the perturbations produced by another. Their value has been calculated by a very similar method to that employed by Leverrier in computing the value of the two terms of similar nature which he has included in his Tables of *Mars*. In general, however, it has been found advisable to use the perturbations of the co-ordinates rather than the perturbations of the elements. For, as a rule, if the former be employed the true value of the resulting coefficient will be given at once, whereas if the latter be used, the value will result from the addition of two large terms with contrary signs, each resulting from a distinct calculation. The values of the coefficients of the disturbing function, and of the perturbations of the elements or co-ordinates, have been derived from Leverrier's Memoirs in the *Annales de l'Observatoire de Paris*. Leverrier's notation is employed throughout.

The first of these terms is due to the combined action of the Earth and *Saturn* on the motion of *Mars*. It has the considerable period of 220·90 years, and the value of

$$
\begin{aligned}
&-0''{\cdot}3388 \sin ([2n''' - n'' - 2n^{v}]\, t + 2\epsilon''' - \epsilon'' - 2\epsilon^{v} + \varpi'')\\
&+0''{\cdot}0250 \sin (\quad\ \ ,,\quad\ \ ,,\quad\ \ ,, \quad + \varpi^{v})\\
&+0''{\cdot}0248 \sin (\quad\ \ ,,\quad\ \ ,,\quad\ \ ,, \quad + \varpi'')
\end{aligned}
$$

Adding and reducing to numbers and it becomes

$$+0''{\cdot}3673 \sin (1{\cdot}630^{\circ}\,[Y - 1852{\cdot}08]).$$

The value of this term in the mean motion of the Earth is given in a short paper of mine in the *Monthly Notices* for

November 1877. In that paper, my object being merely the perturbations in the motion of the Earth, and not in that of *Mars*, I contented myself by merely reversing the value for the principal term in the motion of the Earth, and thus obtained only a fraction of the complete value in the motion of *Mars*. The existence of this new term will appreciably affect the mean motion of *Mars* as determined by Leverrier, possibly by $0''{\cdot}01$, and in this case it would, at the present time, alter the position of *Mars* by $0''{\cdot}25$, in addition to the more direct action which the term itself will have.

The second term is still more important, for its effects cannot be eliminated by a change in the mean motion. It arises from the combined attraction of the Earth and *Jupiter* on the motion of *Mars*, and it has the comparatively short period of 46·52 years. It has the value of

$$\begin{aligned} &-0''{\cdot}2934 \sin ([6n''' - 3n'' - 2n^{\mathrm{IV}}]\, t + 6\epsilon''' - 3\epsilon'' - 2\epsilon^{\mathrm{IV}} - \varpi'''), \\ &+0''{\cdot}0530 \sin (\quad\ \ \, " \qquad\quad " \qquad\quad - \varpi''), \\ &+0''{\cdot}0025 \sin (\quad\ \ \, " \qquad\quad " \qquad\quad + \varpi^{\mathrm{IV}} - 2\varpi'''). \end{aligned}$$

Uniting these separate portions, and reducing to numbers, the term becomes

$$0''{\cdot}3285 \sin (7^{\circ}{\cdot}740\, [Y - 1835{\cdot}75]).$$

This term will therefore change the place of *Mars* by two-thirds of a second in the short period of twenty years, so that in this term alone the place of *Mars* will be affected by this amount since the epoch of Leverrier's Tables. Further, it is probable it will still further alter Leverrier's value of the mean motion, for although its short period would prevent this in a long series of observations, where much weight is attached to the modern observations it will have some influence.

In considering the influence of these terms in the mean motion of *Mars*, it must not be forgotten that the values which have been given are in heliocentric co-ordinates. The first term can alter the geocentric longitude of *Mars* by nearly two seconds of arc, and the second term by more than one and a half second, and as these will systematically affect the observation for several years at a time, they will become very sensible quantities. Thus, from the combined effect of these two terms, the geocentric place of *Mars* during opposition thirty years hence will be four seconds greater than it was at the commencement of the century.

During my investigation I have come across a number of other terms of long period in the mean motion of *Mars* with coefficients of less magnitude than those which have been already mentioned, but with values sufficiently great to render them sensible in delicate observations of *Mars*. They are, in fact, more important than a great number of the terms which are included

by Leverrier in his Tables, and as they might all be included in a single table of single entry, it appears to me that they might be included with advantage in the Tables of *Mars*.

These terms are the following, the epoch being 1800:—

$$-0''.0458 \sin\{[2n' - n - n^{IV}]\, t + 283^\circ 24\} \quad \text{or} \quad +0''.0458 \sin\{7^\circ.53\,[Y - 1836.60]\},$$

period 46·75 years. This term will augment the preceding term, and be confounded with it for a long period.

$$+0''.0420 \sin\{[4n''' - 2n'' - n^{IV}]\, t + 158^\circ 36'\} \quad \text{or} \quad +0''.0420 \sin\{15^\circ.28\,[Y - 1860.33]\},$$

period 23·37 years.

$$-0''.1024 \sin\{[4n''' - 2n' - 2n^{IV}]\, t + 206^\circ 48'\} \quad \text{or} \quad +0''.1024 \sin\{15^\circ.07\,[Y - 1861.48]\},$$

period 23·88 years. This term, with that preceding, will practically form a single term for many years, and this compound term will have a coefficient of 0″·15, and be capable of systematically altering the geocentric place of *Mars* by three-quarters of a second of arc in the very short period of 10 years. All these three, as well as the next term, arise from the combined action of the Earth and *Jupiter*.

$$+0''.0230 \sin\{[13n''' - 7n'' + n^{IV}]\, t + 334^\circ\} \quad \text{or} \quad -0''.0230 \sin\{1^\circ.368\,[Y - 1781]\},$$

period 262·2 years. Despite its long period this term is very small.

The next three terms arise from the combined action of *Jupiter* and *Saturn* on the planet *Mars*.

$$+0''.0243 \sin\{[n''' - 7n^{IV} + 2n^{V}]\, t + 314^\circ 43'\} \quad \text{or} \quad +0''.0243 \sin\{3^\circ.123\,[Y - 1814.50]\},$$

period 115·30 years.

$$+0''.0536 \sin\{[n''' - 8n^{IV} + 4n^{V}]\, t + 199^\circ 30'\} \quad \text{or} \quad +0''.0526 \sin\{2^\circ.505\,[Y - 1807.79]\},$$

period 143·70 years. Both these terms have small coefficients from the different portions neutralising each other.

$$+0''.1145 \sin\{[n''' - 10n^{IV} + 9n^{V}]\, t + 193^\circ 52'\} \quad \text{or} \quad +0''.1145 \sin\{2^\circ.100\,[Y - 1806.62]\},$$

period 171·60 years. This term, with that preceding, will unite for many years to form a compound term with a coefficient of 1″·7, and capable of sensibly altering the position of *Mars*. They will slightly affect the value of the mean motion determined by Leverrier.

The last term is due to the action of *Venus* and the Earth on *Mars*.

$$-0''.0900 \sin\{[8n''' - n' - 2n'']\, t + 52^\circ 1'\} \quad \text{or} \quad -0''.0900 \sin\{0^\circ.874\,[Y - 1740.52]\}.$$

It has a period of 411·7 years.

The terms depending on the argument $[n'-4n'''+6n^{\text{IV}}]$ and $[n'''-9n^{\text{IV}}+7n^{\text{V}}]$ are insensible. The term arising from the combined action of the Earth and *Saturn* with the argument $[19n'''-10n''-3n^{\text{IV}}]$, or of the 6th order of the eccentricities, has the enormous period of 6,000 years, and it has a coefficient of over a second of arc. Its enormous period renders this insensible. It is remarkable, however, for it will be a secular term when the motions of the perihelion are considered. Apart from other considerations, it has been thought well to place the values of these terms on record for the purpose of saving useless labour to subsequent investigators.

Note on a Remarkable Property of the Analytical Expression for the Constant Term in the Reciprocal of the Moon's Radius Vector. By Professor J. C. Adams, M.A., F.R.S.

Let $nt+\varepsilon$ denote the mean longitude of the Moon at the time t; $n't+\varepsilon'$ that of the Sun.

$\xi = nt+\varepsilon-n't-\varepsilon'$, the mean elongation of the Moon from the Sun.

ϕ, the Moon's mean anomaly.

ϕ', that of the Sun.

η, the Moon's mean distance from the ascending node.

$c = \dfrac{d\phi}{ndt}$ and $g = \dfrac{d\eta}{ndt}$, so that $(1-c)\,n$ denotes the mean motion of the Moon's perigee, and $(g-1)\,n$ denotes the mean retrograde motion of the Moon's node, in a unit of time.

Also let e denote the mean eccentricity of the Moon's orbit.

e', the eccentricity of the Sun's orbit.

γ, the sine of half the mean inclination of the Moon's orbit to the ecliptic.

$m = \dfrac{n'}{n}$, the ratio of the mean motion of the Sun to that of the Moon.

μ, the sum of the masses of the Earth and Moon.

$a = \left(\dfrac{\mu}{n^2}\right)^{\frac{1}{3}}$, the mean distance in the purely elliptic orbit which the Moon if undisturbed would describe about the Earth in its actual periodic time.

To fix the ideas, we will suppose the quantities e and γ to be defined as in Delaunay's Theory of the Moon.

If r denote the Moon's radius vector, and if we omit terms depending on the Sun's parallax, then, as is well known, the value of $\dfrac{a}{r}$ may be expanded in an infinite series involving cosines of angles of the form

$$2i\xi \pm j\phi \pm j'\phi' \pm 2k\eta,$$

where i, j, j', k denote any positive integers, including zero, and the coefficient of the term with this argument contains $e^i e'^j \gamma^{2k}$ as a factor, the remaining factor being a function of m, e^2, e'^2, and γ^2.

In particular, there is a constant term in $\frac{a}{r}$, corresponding to the case in which i, j, j', and k are all zero, and this term has the form

$$A + Be^2 + C\gamma^2 + Ee^4 + 2Fe^2\gamma^2 + G\gamma^4 + \&c.,$$

where

$$A = A_0 + A_1 e'^2 + A_2 e'^4 + \&c.$$
$$B = B_0 + B_1 e'^2 + B_2 e'^4 + \&c.$$
$$C = C_0 + C_1 e'^2 + C_2 e'^4 + \&c.$$
$$\&c. \quad \&c. \quad \&c.$$

and A_0, A_1 &c., B_0, B_1 &c., C_0, C_1 &c. are all functions of m.

Plana and, after him, Lubbock, Pontécoulant, and Delaunay have developed the functions of m which occur in the coefficients of the several terms of $\frac{a}{r}$ and of the other coordinates of the Moon, in series of ascending powers of m, and have severally determined, by different methods, the numerical coefficients of the leading terms in these developments.

With respect to the constant term in $\frac{a}{r}$, Plana showed that the quantities denoted above by B_0 and C_0, viz. the coefficients of e^2 and γ^2 in the above constant, both vanish when account is taken of the terms involving m^2 and m^3. Pontécoulant carried the development of the quantities B_0 and C_0 two orders higher, viz. to terms involving m^5, and found that these terms likewise vanish.

These investigations of Plana and Pontécoulant, however, while they show that the coefficients of the above mentioned powers of m vanish by the mutual destruction of the parts of which each of the coefficients is composed, supply no reason why this mutual destruction should take place, and throw no light whatever on the values of the succeeding coefficients in the series.

Thinking it probable that these cases in which the coefficients had been found to vanish were merely particular cases of some more general property, I was led to consider the subject from a new point of view, and on February 22, 1859, I succeeded in proving, not only that the coefficients B_0 and C_0 vanish identically, but that the same thing holds good of the more general coefficients B and C, so that the coefficients of

$$e^2, \ e^2 e'^2, \ e^2 e'^4, \ \&c.$$
$$\gamma^2, \ \gamma^2 e'^2, \ \gamma^2 e'^4, \ \&c.$$

in the constant term of $\frac{a}{r}$ are all identically equal to zero.

Further reflection on the subject led me, several years later, to a simpler and more elegant proof of the property above mentioned.

This new proof was found on February 27, 1868, and I now venture to lay it before the Society. The resulting theorem is remarkable for a degree of simplicity and generality of which the lunar theory affords very few examples.

There are also two remarkable relations between the coefficients of e^4, $e^2\gamma^2$, and γ^4 in the constant term of $\frac{a}{r}$, which we before denoted by E, F, and G. These relations may be thus stated:

If the terms of the quantity c or $\frac{d\phi}{ndt}$ which involve e^2 and γ^2 be denoted by

$$He^2 + K\gamma^2,$$

and similarly if the terms of g or $\frac{d\eta}{ndt}$ which involve e^2 and γ^2 be denoted by

$$Me^2 + N\gamma^2,$$

where H, K, M, and N are functions of m and e'^2,
then we shall have

$$\frac{E}{F} = \frac{H}{K} \text{ and } \frac{F}{G} = \frac{M}{N}.$$

These relations are established by means of the same principle which was employed to prove the theorem above mentioned, viz. that $B = 0$ and $C = 0$.

They were, however, arrived at much later, namely on August 14, 1877.

Analysis.

Let x, y, z denote the rectangular coordinates of an imaginary Moon at any time t, the plane of xy being that of the ecliptic, and the axis of x the origin of longitudes.

Also let x', y' be the rectangular coordinates of the Sun, r' its radius vector, and μ' its mass.

Then if we neglect the terms which involve the Sun's parallax, the equations of motion are

$$\frac{d^2x}{dt^2} + \frac{\mu x}{r^3} + \frac{\mu' x}{r'^3} = \frac{3\mu' x'}{r'^5}(xx' + yy'),$$

$$\frac{d^2y}{dt^2} + \frac{\mu y}{r^3} + \frac{\mu' y}{r'^3} = \frac{3\mu' y'}{r'^5}(xx' + yy'),$$

$$\frac{d^2z}{dt^2} + \frac{\mu z}{r^3} + \frac{\mu' z}{r'^3} = 0.$$

Now let x_1, y_1, z_1 be the rectangular coordinates, and r_1 the radius vector, of another imaginary Moon at the same time t as before, so that the same equations of motion hold good, and μ, μ', x', y', and r' are unaltered.

Hence

$$\frac{d^2x_1}{dt^2}+\frac{\mu x_1}{r_1^3}+\frac{\mu' x_1}{r'^3}=\frac{3\mu' x'}{r'^5}(x_1x'+y_1y'),$$

$$\frac{d^2y_1}{dt^2}+\frac{\mu y_1}{r_1^3}+\frac{\mu' y_1}{r'^3}=\frac{3\mu' y'}{r'^5}(x_1x'+y_1y'),$$

$$\frac{d^2z_1}{dt^2}+\frac{\mu z_1}{r_1^3}+\frac{\mu' z_1}{r'^3}=0.$$

Multiply the first set of equations by x_1, y_1, z_1 respectively, and subtract their sum from the sum of the similar equations in x_1, y_1, z_1 multiplied by x, y, z respectively.

Thus we find

$$\left(x\frac{d^2x_1}{dt^2}-x_1\frac{d^2x}{dt^2}\right)+\left(y\frac{d^2y_1}{dt^2}-y_1\frac{d^2y}{dt^2}\right)+\left(z\frac{d^2z_1}{dt^2}-z_1\frac{d^2z}{dt^2}\right)$$
$$+\mu(xx_1+yy_1+zz_1)\left(\frac{1}{r_1^3}-\frac{1}{r^3}\right)=0;$$

or

$$\frac{d}{dt}\left(x\frac{dx_1}{dt}-x_1\frac{dx}{dt}\right)+\frac{d}{dt}\left(y\frac{dy_1}{dt}-y_1\frac{dy}{dt}\right)+\frac{d}{dt}\left(z\frac{dz_1}{dt}-z_1\frac{dz}{dt}\right)$$
$$+\mu(xx_1+yy_1+zz_1)\left(\frac{1}{r_1^3}-\frac{1}{r^3}\right)=0.$$

Hence the quantity

$$(xx_1+yy_1+zz_1)\left(\frac{1}{r_1^3}-\frac{1}{r^3}\right)$$

is a complete differential coefficient with respect to t, and therefore when developed in cosines of angles which increase proportionally to the time it cannot contain any constant term.*

Now

$$xx_1+yy_1+zz_1=\frac{1}{2}\{2rr_1+(r-r_1)^2-(x-x_1)^2-(y-y_1)^2-(z-z_1)^2\}$$

and

$$\left(\frac{1}{r_1^3}-\frac{1}{r^3}\right)=\left(\frac{1}{r_1}-\frac{1}{r}\right)\left\{\frac{3}{rr_1}+\left(\frac{1}{r_1}-\frac{1}{r}\right)^2\right\}.$$

* We may remark here that neither of the quantities

$$(xx_1+yy_1)\left(\frac{1}{r_1^3}-\frac{1}{r^3}\right),$$

$$zz_1\left(\frac{1}{r_1^3}-\frac{1}{r^3}\right),$$

can contain any constant term, but no use is made of this in what follows.

Hence, if $x - x_1$, $y - y_1$, $z - z_1$, and therefore also $r - r_1$, and $\frac{1}{r_1} - \frac{1}{r}$ be quantities of the first order with respect to any symbol, then

$$(xx_1 + yy_1 + zz_1)\left(\frac{1}{r_1^3} - \frac{1}{r^3}\right)$$

will differ from $3\left(\frac{1}{r_1} - \frac{1}{r}\right)$ by a quantity of the third order only.

Hence, in the case supposed, the quantity $\frac{1}{r_1} - \frac{1}{r}$ cannot contain any constant term of lower order than the third.

More generally, the constant part of $\frac{1}{r_1} - \frac{1}{r}$ cannot be of a lower order than the constant part of the product of the quantity $\frac{1}{r_1} - \frac{1}{r}$ multiplied by one or other of the quantities

$$\left(\frac{1}{r_1} - \frac{1}{r}\right)^2, \text{ or } (x - x_1)^2 + (y - y_1)^2 + (z - z_1)^2 - (r - r_1)^2.$$

Now, as the two systems x, y, z and x_1, y_1, z_1 satisfy the same differential equations, the solutions can only differ from each other by involving different values of the arbitrary constants.

By applying the principle just stated to four different cases of variation of the arbitrary constants, we shall be able to prove the properties already enunciated, viz.

$$B = 0, \quad C = 0, \quad \frac{E}{F} = \frac{H}{K}, \quad \text{and} \quad \frac{F}{G} = \frac{M}{N}.$$

Let

$$x = u \cos(nt + \epsilon) - v \sin(nt + \epsilon),$$
$$y = u \sin(nt + \epsilon) + v \cos(nt + \epsilon),$$

and similarly

$$x_1 = u_1 \cos(nt + \epsilon) - v_1 \sin(nt + \epsilon),$$
$$y_1 = u_1 \sin(nt + \epsilon) + v_1 \cos(nt + \epsilon),$$

where $nt + \epsilon$ is supposed to retain the same value as before.

Then

$$(x - x_1)^2 + (y - y_1)^2 = (u - u_1)^2 + (v - v_1)^2.$$

Hence, in the statement of our principle, we may replace

$$(x - x_1)^2 + (y - y_1)^2 + (z - z_1)^2 - (r - r_1)^2$$

by

$$(u - u_1)^2 + (v - v_1)^2 + (z - z_1)^2 - (r - r_1)^2.$$

For the sake of simplicity, we will take the quantity which was before denoted by a as our unit of length, so that, instead of

the quantity formerly designated by $\frac{a}{r}$, we shall write simply $\frac{1}{r}$.

Now it is known, *a priori*, that the values of r and u, as well as that of $\frac{1}{r}$, may be developed in an infinite series involving *cosines* of angles of the form

$$2i\xi \pm j\phi \pm j'\phi' \pm 2k\eta,$$

where i, j, j', and k denote any positive integers whatever, including zero, and that the value of v may be developed in a similar series involving *sines* of the same angles.

Also we know that the coefficient of the term with the above argument occurring in any of these series contains $e^j e'^{j'} \gamma^{2k}$ as a factor, the remaining factor being a function of m, e^2, e'^2 and γ^2.

Similarly we know that the value of z may be developed in an infinite series involving *sines* of angles of the form

$$2i\xi \pm j\phi \pm j'\phi' \pm (2k+1)\,\eta,$$

and that the coefficient of the term with this argument contains $e^j e'^{j'} \gamma^{2k+1}$ as a factor, the remaining factor being a function of m, e^2, e'^2 and γ^2, as in the former case.

It is essential to observe that $\frac{1}{r}$, r, u, and v involve only even powers of γ, while z involves only odd powers of the same quantity.

Having made these preliminary observations, we are now in a position to apply our principle to the four cases already alluded to.

Case I.

First, suppose that the values of x, y, z are those belonging to the solution in which e and γ vanish, therefore all the arguments in the values of $\frac{1}{r}$, r, u, and v will be of the form $2i\xi \pm j'\phi'$ and z will vanish.

Also let the values of x_1, y_1, z_1 belong to the solution in which e has a finite value, but γ is still $= 0$, while $nt+\varepsilon$, and therefore also n, retains the same value as before.

Hence z_1 also vanishes, and therefore $z - z_1 = 0$.

Then all the arguments which occur in the values of $\frac{1}{r}$, r, u, and v will also occur in those of $\frac{1}{r_1}$, r_1, u_1, and v_1, but the coefficients of the corresponding terms will differ by a quantity which contains e^2 as a factor.

Let the terms with these arguments be called terms of the *first class*.

Also there will be additional terms in the values of $\frac{1}{r_1}$, r_1, u_1, and v_1, with arguments of the form

$$2i\xi \pm j\phi \pm j'\phi',$$

where j does not vanish, and the coefficients of these terms will all contain e as a factor.

Let the terms with these arguments be called terms of the *second class.*

Now, in the formation of the quantities

$$\left(\frac{1}{r_1}-\frac{1}{r}\right)^3 \text{ and } \left(\frac{1}{r_1}-\frac{1}{r}\right)\{(u-u_1)^2+(v-v_1)^2-(r-r_1)^2\}$$

terms with the argument zero can only arise by multiplying together three terms of the first class, one term of the first and two of the second class, or three terms of the second class, one of which at least involves e^2 as a factor. Such a term formed in the first of these ways would be of the order of e^6 at least, while one formed in the second or third of these ways would be of the order of e^4 at least. Hence, by the principle before proved, the value of $\frac{1}{r_1}-\frac{1}{r}$ can contain no constant term of the order of e^2.

Hence $B = 0$ generally, and as this holds good for every value of e', we must have

$$B_0 = 0,\ B_1 = 0,\ B_2 = 0,\ \&c.$$

Case II.

In the next place, let the values x, y, z, as before, belong to the solution in which e and γ vanish, and let the values x_1, y_1, z_1 belong to the solution in which e is still equal to 0, but γ has a finite value, while $nt+\epsilon$, and therefore also n, retains the same value as before.

Then all the arguments which occur in the values of $\frac{1}{r}$, r, u, and v likewise occur in those of $\frac{1}{r_1}$, r_1, u_1, and v_1, but the coefficients of the corresponding terms will differ by a quantity which contains γ^2 as a factor.

Also there will be additional terms in the values of $\frac{1}{r_1}$, r_1, u_1, and v_1, with arguments of the form

$$2i\xi \pm j'\phi' \pm 2kn,$$

where k does not vanish, and these will also contain γ^2 as a factor in every term.

Hence $\frac{1}{r_1}-\frac{1}{r}$, $r-r_1$, $u-u_1$, and $v-v_1$ will contain γ^2 as a factor in every term.

Also $z = 0$, and therefore $(z-z_1)^2 = z_1^2$, which will also contain γ^2 as a factor in every term.

Hence $\left(\frac{1}{r_1}-\frac{1}{r}\right)^3$ will be of the order of γ^6 at least, while

$$\left(\frac{1}{r_1}-\frac{1}{r}\right)\{(u-u_1)^2+(v-v_1)^2+(z-z_1)^2-(r-r_1)^2\}$$

will be of the order of γ^4 at least.

Therefore, by the same principle as before, the value of $\frac{1}{r_1}-\frac{1}{r}$ can contain no constant term of the order of γ^2.

That is, $C = 0$ generally; and as this holds good for every value of e', we must have

$$C_0 = 0,\ C_1 = 0,\ C_2 = 0,\ \&c.$$

Case III.

Next, let the values x, y, z belong to the solution in which γ vanishes and e is finite, while x_1, y_1, z_1 belong to the general case in which e_1 and γ are both finite, the value of e being now changed to e_1 while $nt+\varepsilon$, and therefore also n, retains the same value as before.

Then all the arguments which occur in the values of $\frac{1}{r}$, r, u, and v, and which are of the form

$$2i\xi \pm j\phi \pm j'\phi',$$

will occur unchanged in the values of $\frac{1}{r_1}$, r_1, u_1, and v_1, provided that ϕ, and therefore also $\frac{d\phi}{ndt}$ or c, remains unchanged, but the coefficients of the corresponding terms will differ by quantities which involve either $e-e_1$ or γ^2 as a factor.

Let the terms with these arguments be called terms of the *first class.*

Also there will be additional terms in the values of $\frac{1}{r_1}$, r_1, u_1, and v_1, the arguments of which are of the form

$$2i\xi \pm j\phi \pm j'\phi' \pm 2k\eta,$$

where k does not vanish. The coefficients of these terms will all contain γ^2 as a factor.

Call the terms with these arguments terms of the *second class.*

And $(z-z_1)^2 = z_1^2$, which contains γ^2 as a factor in every term.

Now the condition that c remains unchanged gives us the following relation between $e^2, e_1{}^2$, and γ^2:

$$\mathrm{H}e^2 = \mathrm{H}e_1{}^2 + \mathrm{K}\gamma^2,$$

taking into account only the terms of lowest order in e^2, $e_1{}^2$, and γ^2.

Hence, ultimately,

$$\gamma^2 = \frac{\mathrm{H}}{\mathrm{K}}(e^2 - e_1{}^2).$$

If this value of γ^2 be substituted for it, we see that every term in the values of $\frac{1}{r_1} - \frac{1}{r}$, $r - r_1$, $u - u_1$, $v - v_1$, and $(z - z_1)^2$ will be divisible by $e - e_1$.

Hence the constant part of $\frac{1}{r_1} - \frac{1}{r}$ will be divisible by $(e - e_1)^2$, and therefore also by $(e^2 - e_1{}^2)^2$, since this constant part involves only even powers of e^2 and $e_1{}^2$.

That is,

$$\mathrm{E}(e_1{}^4 - e^4) + 2\mathrm{F}e_1{}^2\gamma^2$$

is divisible by $(e^2 - e_1{}^2)^2$; or,

$$\mathrm{E}(e_1{}^4 - e^4) + 2\mathrm{F}e_1{}^2\frac{\mathrm{H}}{\mathrm{K}}(e^2 - e_1{}^2)$$

is divisible by $(e^2 - e_1{}^2)^2$.

Divide by $e^2 - e_1{}^2$ and then put $e_1{}^2 = e^2$, therefore

$$-2\mathrm{E}e^2 + 2\mathrm{F}\frac{\mathrm{H}}{\mathrm{K}}e^2 = 0,$$

or

$$\frac{\mathrm{E}}{\mathrm{F}} = \frac{\mathrm{H}}{\mathrm{K}}.$$

Case IV.

Lastly, let the values of x, y, z belong to the solution in which e vanishes and γ is finite, while x_1, y_1, z_1 belong to the general case in which e and γ_1 are both finite, the value of γ being changed to γ_1 while $nt + \varepsilon$, and therefore also n, retains the same value as before.

Then all the arguments which occur in the values of $\frac{1}{r}$, r, u, and v, and which are of the form

$$2i\xi \pm j'\phi' \pm 2k\eta,$$

will occur unchanged in the values of $\frac{1}{r_1}$, r_1, u_1, and v_1, provided that η, and therefore also $\frac{d\eta}{ndt}$ or g, remains unchanged, but the coefficients of the corresponding terms will differ by quantities which involve either e^2 or $\gamma^2 - \gamma_1{}^2$ as a factor.

Let the terms with these arguments be called terms of the *first class.*

Also there will be additional terms in the values of $\frac{1}{r_1}$, r_1, u_1, and v_1, the arguments of which are of the form

$$2i\xi \pm j\phi \pm j'\phi' \pm 2k\eta,$$

where j does not vanish. The coefficients of these terms will all involve e as a factor.

Call the terms with these arguments terms of the *second class.*

Moreover, all the arguments which occur in the value of z, and which are of the form

$$2i\xi \pm j'\phi' \pm (2k+1)\,\eta,$$

will occur unchanged in the value of z_1, but the coefficients of the corresponding terms will differ by quantities which involve either e^2 or $\gamma - \gamma_1$ as a factor.

Let the terms with these arguments be called terms of the *first class.*

Also there will be additional terms in the value of z_1, the arguments of which are of the form

$$2i\xi \pm j\phi \pm j'\phi' \pm (2k+1)\,\eta,$$

where j does not vanish. The coefficients of these terms will all involve $e\gamma_1$ as a factor.

Call the terms with these arguments terms of the *second class.*

Now the condition that g remains unchanged gives us the following relation between e^2, γ^2, and ${\gamma_1}^2$:

$$N\gamma^2 = Me^2 + N{\gamma_1}^2,$$

taking into account only the terms of lowest order in e^2, γ^2, and ${\gamma_1}^2$.

Hence, ultimately,

$$e^2 = \frac{N}{M}(\gamma^2 - {\gamma_1}^2).$$

If this value of e^2 be substituted for it, we see that every term of the first class in the values of

$$\frac{1}{r_1} - \frac{1}{r}, \quad r - r_1, \quad u - u_1, \quad \text{and} \quad v - v_1$$

will be divisible by $\gamma^2 - {\gamma_1}^2$, and that every term of the second class in the values of the same quantities will be divisible by e. Also every term of the first class in the value of $z - z_1$ will be divisible by $\gamma - \gamma_1$, and every term of the second class in the value of the same quantity will be divisible by $e\gamma_1$.

Now in the formation of the quantities

$$\left(\frac{1}{r_1}-\frac{1}{r}\right)^3,\quad \left(\frac{1}{r_1}-\frac{1}{r}\right)\{(u-u_1)^2+(v-v_1)^2-(r-r_1)^2\},\quad \text{and}\quad \left(\frac{1}{r_1}-\frac{1}{r}\right)(z-z_1)^2,$$

terms with the argument zero can only arise by multiplying together either

(1) Three terms of the first class;

(2) One term of the first and two of the second class;

or (3) Three terms of the second class, one of which at least involves e^2 as a factor.

Such a term formed in the first of these ways would be divisible by $(\gamma-\gamma_1)^3$ and therefore by $(\gamma^2-\gamma_1^2)^3$, since it can only involve even powers of γ and γ_1.

Such a term formed in the second of these ways would be divisible by $e^2(\gamma-\gamma_1)$ and therefore by $e^2(\gamma^2-\gamma_1^2)$ or by $(\gamma^2-\gamma_1^2)^2$.

Also such a term formed in the third of these ways would be divisible by e^4 or by $(\gamma^2-\gamma_1^2)^2$.

Hence, by the same principle as before, the value of $\frac{1}{r_1}-\frac{1}{r}$ must be divisible by $(\gamma^2-\gamma_1^2)^2$.

That is

$$2Fe^2\gamma_1^2+G(\gamma_1^4-\gamma^4)$$

is divisible by $(\gamma^2-\gamma_1^2)^2$; or

$$2F\frac{N}{M}(\gamma^2-\gamma_1^2)\gamma_1^2-G(\gamma^4-\gamma_1^4)$$

is divisible by $(\gamma^2-\gamma_1^2)^2$.

Now divide by $\gamma^2-\gamma_1^2$, and then put $\gamma_1^2=\gamma^2$; therefore

$$2F\frac{N}{M}\gamma^2-2G\gamma^2=0,$$

or

$$\frac{F}{G}=\frac{M}{N},$$

which is the last of the relations announced above.

The results obtained in Cases III. and IV. may be rendered more general in the following manner:—

Let P denote the constant term in the reciprocal of the Moon's radius vector, considered as a function of e^2 and γ^2.

Then, taking e^2, e_1^2, and γ^2 to be related as in Case III., we have, by the same reasoning as before,

$$0=\frac{dP}{d(e^2)}(e_1^2-e^2)+\frac{dP}{d(\gamma^2)}\gamma^2+\text{terms of higher dimensions in } e_1^2-e^2 \text{ and } \gamma^2.$$

Also

$$0=\frac{dc}{d(e^2)}(e_1^2-e^2)+\frac{dc}{d(\gamma^2)}\cdot\gamma^2+\text{terms of higher dimensions in } e_1^2-e^2 \text{ and } \gamma^2.$$

Hence, we have ultimately, when $e_1^2 = e^2$, and $\gamma^2 = 0$,

$$\text{Limit of } \frac{\gamma^2}{e^2 - e_1^2} = \frac{\dfrac{dP}{d(e^2)}}{\dfrac{dP}{d(\gamma^2)}} = \frac{\dfrac{dc}{d(e^2)}}{\dfrac{dc}{d(\gamma^2)}},$$

in which γ^2 is to be put $= 0$ after the differentiations. The relation thus deduced holds good for all values of e^2. By equating the coefficients of e^2 on the two sides of the equation

$$\frac{dP}{d(c^2)} \cdot \frac{dc}{d(\gamma^2)} = \frac{dP}{d(\gamma^2)} \cdot \frac{dc}{d(c^2)},$$

we find $\dfrac{E}{F} = \dfrac{H}{K}$, as before.

Also, by equating the coefficients of higher powers of e^2, we obtain other relations between the coefficients of terms of higher orders in the value of P.

Similarly, taking e^2, γ^2, and γ_1^2 to be related as in Case IV., we have, by the same reasoning as before,

$$0 = \frac{dP}{d(e^2)} \cdot e^2 + \frac{dP}{d(\gamma^2)} (\gamma_1^2 - \gamma^2) + \text{terms of higher dimensions in } e^2 \text{ and } \gamma_1^2 - \gamma^2.$$

Also

$$0 = \frac{dg}{d(c^2)} \cdot e^2 + \frac{dg}{d(\gamma^2)} (\gamma_1^2 - \gamma^2) + \text{terms of higher dimensions in } e^2 \text{ and } \gamma_1^2 - \gamma^2.$$

Hence, we have ultimately, when $e^2 = 0$ and $\gamma_1^2 = \gamma^2$,

$$\text{Limit of } \frac{\gamma^2 - \gamma_1^2}{e^2} = \frac{\dfrac{dP}{d(e^2)}}{\dfrac{dP}{d(\gamma^2)}} = \frac{\dfrac{dg}{d(e^2)}}{\dfrac{dq}{d(\gamma^2)}},$$

in which e^2 is to be put $= 0$ after the differentiations. The result thus deduced holds good for all values of γ^2. By equating the coefficients of γ^2 on the two sides of the equation

$$\frac{d(P)}{d(c^2)} \cdot \frac{dg}{d(\gamma^2)} = \frac{dP}{d(\gamma^2)} \cdot \frac{dg}{d(e^2)},$$

we find $\dfrac{F}{G} = \dfrac{M}{N}$, as before.

Similarly, by equating the coefficients of higher powers of γ^2, we obtain other relations between the coefficients of terms of higher orders in the value of P.

It may not be without interest to give here the result which I have obtained for the development of the constant term in the reciprocal of the Moon's radius vector.

The expression includes, besides the terms spoken of in the foregoing paper, an additional term depending on the square of the Sun's parallax. Reintroducing the symbol a to denote the length before defined, which in the paper has been taken as the unit of length, I find

The constant term in $\frac{a}{r}$

$$= 1 + \frac{1}{6}m^2 - \frac{179}{288}m^4 - \frac{97}{48}m^5 - \frac{757}{162}m^6 - \frac{4039}{432}m^7 - \frac{34751189}{1990656}m^8 - \frac{31013527}{995328}m^9$$
$$+ e'^2\left[\frac{1}{4}m^2 - \frac{799}{192}m^4 - \frac{873}{32}m^5 - \frac{287849}{2304}m^6 - \frac{268607}{576}m^7\right]$$
$$+ e'^4\left[\frac{5}{16}m^2 - \frac{5401}{384}m^4 - \frac{18527}{128}m^5\right]$$
$$+ \frac{a^2}{a'^2}\left[\frac{3}{16}m^2 + \frac{75}{128}m^3\right]$$
$$+ e^4\left[\frac{1}{16}m^2 + \frac{225}{128}m^3\right]$$
$$+ e^2\gamma^2\left[2m^2 + \frac{63}{8}m^3\right]$$
$$+ \gamma^4\left[-m^2 + \frac{9}{8}m^3\right],$$

where e and γ have the same significations as in Delaunay's Theory.

The method which I employed in obtaining this expression is closely related to my first method, above alluded to, of proving the evanescence of the coefficients B and C.

The coefficients of e^4 and γ^4 were found independently, and from each of these, by means of the relations proved above, was derived a value of the coefficient of $e^2\gamma^2$. The perfect coincidence of these values supplied a test of the correctness of the calculations.

The terms of c and g which are required for this verification are the following:

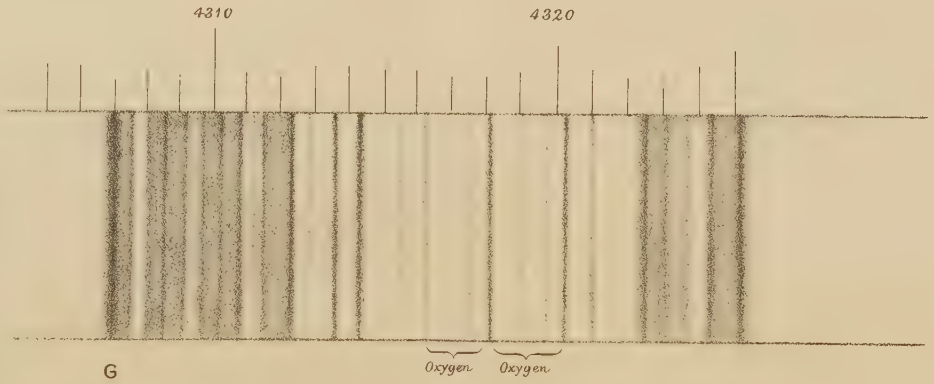
$$c = \ldots + e^2\left(\frac{3}{8}m^2 + \frac{675}{64}m^3\right) + \gamma^2\left(6m^2 + \frac{189}{8}m^3\right) + \ldots$$

$$g = \ldots + e^2\left(\frac{3}{2}m^2 + \frac{189}{32}m^3\right) - \gamma^2\left(\frac{3}{2}m^2 - \frac{27}{16}m^3\right) + \ldots$$

I hope to lay the details of these calculations before the Society on some future occasion.

ROYAL OBSERVATORY GREENWICH.

SOLAR SPECTRUM NEAR G AS SEEN WITH HALF-PRISM SPECTROSCOPE.



PROF. DRAPER'S BRIGHT LINES.

Spottiswoode & Cº Lith London.

On the Existence of Bright Lines in the Solar Spectrum.

By W. H. M. Christie, Esq.

Since Professor H. Draper's announcement that bright lines corresponding to those of oxygen were to be detected in the solar spectrum, I have repeatedly examined various parts of the spectrum, and more particularly the neighbourhood of the G line, in the hope of being able to verify this important announcement. The result, however, has been that certain difficulties as regards the existence of bright lines have presented themselves, and I think it desirable to state these without further delay, although I have not been able to devote as much time to the inquiry as I could have wished. The lines in the solar spectrum present such a different appearance, according to the power of the spectroscope used, that a description of the aspect of the spectrum in the neighbourhood of the G line as seen with the half-prism spectroscope of the Royal Observatory, Greenwich, may throw some light on the question. With this spectroscope many fine lines, not shown in Ångström's or Kirchhoff's maps, or in Professor Draper's photograph, are readily seen, and the stronger absorption lines are comparatively narrow and sharply defined. As a consequence of this a space between two dark lines which, with a spectroscope of lower power, looks like a bright line, loses this appearance altogether, and seems to be nothing but the background of continuous spectrum. In the diagram representing the spectrum on the less refrangible side of G, four spaces are formed by the strong lines at 4314·4, 4316·3, 4318·1, and 4320·2, which, with a lower dispersive power or less perfect definition, might be taken as bright lines, and, in fact, Professor H. Draper has identified the two inner as a double line of oxygen. But, as seen at Greenwich, the spaces are each about ten times the breadth of the dark lines and of perfectly even tint, without any trace of fuzziness at the edges. Now it seems difficult to explain the existence of bright lines which remain of sensible breadth and sharply defined at the edges when the slit of the spectroscope is closed. In ordinary cases, where a bright line (such as H_β at atmospheric pressure) has a breadth much greater than that of the slit, it is fuzzy at the edges, whereas the spaces or 'bright lines' in question are perfectly even in tint. Further, I have not been able to distinguish the slightest difference in tint in the whole portion from 4312 to 4322, and this under conditions which showed, in each of the spaces, two fine absorption lines of which not a trace is to be found on Professor Draper's photograph. In making this statement, however, it must be understood that I am referring to the Albertype print, in which, doubtless, some of the definition of the original negative would be lost. I have not had an opportunity of seeing the latter. However this may be, the definition, when these observations

with the half-prism spectroscope were made, was sufficiently good to show ten absorption lines in a space where Angström's map shows only three. The circumstance that there are absorption lines in these spaces seems to me to present another difficulty in accepting the view that the spaces in question are bright lines.

As Professor H. Draper attaches much importance to the evidence of photography, I have also taken a few photographs of this part of the spectrum, in which the relative breadths of the absorption lines, as compared with the spaces between them, and the fine lines seen in these spaces agree exactly with the eye-view. These photographs, which I beg to lay before the meeting, were taken with exposures ranging from 1^s to 5^s (according to the state of the sky) the width of the slit being about 1-5000th of an inch. But hitherto no comparison has been made at Greenwich with the spectrum of oxygen, my attention having been directed entirely to the character of the solar spectrum apart from the question of coincidences of spaces with the bright lines of oxygen. The comparison of the two spectra presents great practical difficulties, and the character of the solar spectrum is, after all, the question of primary importance. It might seem, at first sight, that the coincidence of a large number of lines of oxygen with spaces in the solar spectrum would be sufficient in itself to prove that these spaces are really bright lines, but it must be remembered that, as there are no coincidences of oxygen with dark lines in the solar spectrum, every line of oxygen must correspond approximately to a space, and this is all that can be asserted, so far, from the Albertype print of Professor Draper's photograph, in which the dark lines and spaces are of about equal breadth and fuzzy at the edges. If, however, an *exact* coincidence could be established within small limits of error on the original negative, the case would be altered. But the spectrum must be magnified many times to give the requisite accuracy. In this connexion it may be well to mention that the diagram is on a scale fifteen times that of Professor Draper's photograph and represents fairly the accuracy attainable in eye observation.

The observations were made with the half-prism spectroscope, in which a train of two compound half-prisms (direct vision) gives a dispersion of 75° from A to H, equivalent to 15 prisms of 60°. The spectroscope was used in connexion with the Great Equatoreal of the Royal Observatory, which forms an image of the Sun two inches in diameter on the slit, thus avoiding the confusion of definition which, as Capt. Abney has pointed out, would, to a certain extent, result from the effect of the Sun's rotation when a heliostat is used. In this examination of the spectrum I have received much assistance from Mr. Maunder.

1878, *June* 13.

Ephemeris for finding the position of the Satellite of Neptune.
By Mr. A. Marth.

Gr. Noon. 1878.	P °	*a* ″	*b* ″	log. *a*	log. *b*	Long. °	Diff. °
Aug. 13	311·71	16·53	5·87	1·2182	0·7690	245·64	
							612·59
23	311·69	16·62	5·91	·2206	·7713	138·23	
							·54
Sept. 2	311·65	16·70	5·93	·2228	·7729	30·77	
							·49
12	311·58	16·78	5·94	·2248	·7737	283·26	
							·44
22	311·48	16·85	5·94	·2266	·7738	175·70	
							·40
Oct. 2	311·36	16·90	5·93	1·2280	0·7731	68·10	
							612·36
12	311·22	16·95	5·91	·2291	·7717	320·46	
							·33
22	311·08	16·97	5·88	·2297	·7696	212·79	
							·31
Nov. 1	310·93	16·98	5·85	·2299	·7669	105·10	
							·31
11	310·79	16·97	5·80	·2296	·7636	357·41	
							·31
21	310·65	16·94	5·75	·2288	·7600	249·72	
							·32
Dec. 1	310·52	16·89	5·70	1·2276	0·7561	142·04	
							612·34
11	310·41	16·83	5·65	·2261	·7521	34·38	
							·37
21	310·33	16·76	5·60	·2242	·7482	286·75	
							·41
31	310·27	16·67	5·55	·2220	·7445	179·16	
							·46
1879. Jan. 10	310·24	16·58	5·51	·2196	·7412	71·62	
							·50
20	310·23	16·49	5·48	·2171	·7385	324·12	
							·55
30	310·25	16·39	5·45	·2146	·7363	216·67	
							612·61
Feb. 9	310·31	16·30	5·43	1·2121	0·7347	109·28	

P, angle of position of the minor axis of the apparent orbit in the direction of superior conjunction.

a, *b*, major and minor semi-axes of apparent orbit.

Long. = longitude of the satellite in its orbit, reckoned from the point which is in superior conjunction with the planet.

The values of the table are to be interpolated for the times for which the places of the satellite are required, and the position-angles p and distances s are then found by

$$s \sin (P - p) = a \sin \text{long.}$$

$$s \cos (P - p) = b \cos \text{long.}$$

To know whereabout the satellite is situated it will be sufficient

to know the approximate times of its superior ($p = 311°$) and inferior ($p = 131°$) conjunctions, and to construct the apparent ellipse.

1878.	G.M.T. h		1878.	G.M.T. h		1878.	G.M.T. h	
Aug. 14	21	sup.	Oct. 15	14	inf.	Dec. 16	8	sup.
17	19	inf.	18	13	sup.	19	6	inf.
20	18	sup.	21	11	inf.	22	5	sup.
23	16	inf.	24	10	sup.	25	3	inf.
26	15	sup.	27	8	inf.	28	2	sup.
29	13	inf.	30	7	sup.	31	0	inf.
Sept. 1	12	sup.	Nov. 2	5	inf.	1879.		
4	10	inf.	5	4	sup.	Jan. 2	23	sup.
7	9	sup.	8	2	inf.	5	21	inf.
10	8	inf.	11	1	sup.	8	20	sup.
13	6	sup.	14	0	inf.	11	18	inf.
16	5	inf.	16	22	sup.	14	17	sup.
19	3	sup.	19	21	inf.	17	16	inf.
22	2	inf.	22	19	sup.	20	14	sup.
25	0	sup.	25	18	inf.	23	13	inf.
27	23	inf.	28	16	sup.	26	11	sup.
30	21	sup.	Dec. 1	15	inf.	29	10	inf.
Oct. 3	20	inf.	4	13	sup.	Feb. 1	8	sup.
6	18	sup.	7	12	inf.	4	7	inf.
9	17	inf.	10	11	sup.	7	5	sup.
12	15	sup.	13	9	inf.	10	4	inf.

Note on the Duplicity of the Companion to Rigel.

By S. W. Burnham, Esq.

More than six years ago, when using a power of 400 on my 6-inch Clark Refractor, I noticed what appeared to be a slight but decided elongation in the companion to *Rigel*, nearly in the direction of the primary. I called the attention of observers to this (*English Mechanic*, February 9, 1872), and subsequently examined the star many times with the same instrument, but was never able to satisfy myself fully that the small star was really double, and the evidence from other quarters was either negative or unfavourable. Some years later Mr. Herbert Sadler wrote me that he had noticed the same peculiar appearance in the small star, independently, I believe, and I again, in 1876,

examined it on several very favourable occasions, finding the same appearance as before. I could not feel quite certain that it was not due to vertical elongation, although, after the precautions observed, it seemed very improbable. The attention of several astronomers in this country and Europe having larger apertures at command was specially requested to aid in deciding the question. Nothing having been received changing or modifying my own prior observations, at the first opportunity, towards the end of 1877, the 18½-inch Clark Equatoreal of the Dearborn Observatory was brought to bear, and the small star carefully examined whenever the air was sufficiently steady. There were few nights, however, at this time perfect enough to allow of the use of very high powers at a moderate altitude. Later the conditions were better, and I give below the measures when the disk of the small star was sharply enough defined to make it worth while attempting to use the micrometer. The star was examined on a number of other nights earlier, but generally the images were too unsteady to give anything more than a suspected, or uncertain elongation. But on no occasion, at any time, was the appearance such as to discourage further attempts.

February 3. Measured P = 160°·3. There does not seem to be much doubt of the duplicity of the small star. Power 900.

„ 26. Measured as follows: P = 179°·1; D = 0″·31. B is certainly double. Splendid definition. There can be no doubt now. Power 900.

March 4. Measures good. P = 178°·9; D = 0″·40. Companion is certainly double. There can be no mistake in the slight elongation measured, but excessively difficult. Measured distance is a diameter. Power 900.

It should be stated that the distance measures given above more properly belong to the long diameter of the small star than to the central distance, as otherwise the stars would, with this power, be widely separated. The real distance cannot exceed 0″·2, and is probably materially less. The position-angle measures were made with the large star out of the field, so that its direction would not bias the setting of the wires on the close pair. Several attempts were made later, but the air was not steady enough to add anything of value to the results already obtained, and no measures could be made. It may seem strange that a star so excessively close as this should have been even suspected with an aperture of only six inches, and it is not easy of explanation. I can only state that under suitable conditions single stars of this magnitude are seen with perfectly round, sharply cut, and well-defined disks, and any eccentricity, however small, might, with careful attention, be detected. If the distance were not under 0″·3 there would not be a moment's hesitation in pronouncing such a star double. I trust astronomers having sufficiently powerful and perfect instruments will give the star

special attention. It is a severe test, and a strictly first-class telescope, whether large or small, is necessary to deal with it.

Rigel has a minute distant attendant, discovered by Mitchel at Cincinnati in 1846, and rated by him 15 magnitude. I made two measures as follows:—

	°	″
October 24	P = 1·7	D = 44·38.
„ 31	1·3	44·27.

This star has never been measured before.

Chicago, April 12.

New Double Stars. By S. W. Burnham, Esq.

I desire to call the attention of double star observers, in advance of the publication of my observations during the past year, to a few of the recent discoveries with the 18½-inch refractor of the Dearborn Observatory, in the hope that other measures may be made during the present season. The prevailing unfavourable weather here for several months has made it impossible to repeat the measures of some of the stars as often as was desired.

		°	″
1	51 Cygni	P = 102·3	D = 3·13
2	8 Andromedæ	162·0	7·40
3	27 Piscium	264·9	1·44
4	52 Herculis	309·4	1·84
5	15 Can. Ven.	284·9	1·22
6	ι′ Libræ, BC	24·3	1·86
7	Serpentis 55	356·6	0·42
8	B.A.C. 4559	57·0	0·26
9	γ Draconis	152·3	20·61

(5) 15 *Can. Ven.* is the preceding star of the wide pair, Σ 24, App. I.

(6) As a wide pair, this is H VI. 44 = Sh. 376. Herschel's companion is double, the system somewhat resembling *μ Herculis*. There appears to be a decided change in the distance from the large star. Sh. found 111°·6 : 50″·3. From three nights' measures I get 110°·5 : 57″·46.

(7) The place of this star is R.A. $15^h\ 37^m$; Decl. +14° 3′.

(8) This is a large star in *Boötes* (5 magnitude, according to Argelander and Heis), the place of which is R.A. $13^h\ 33^m$; Decl. +11° 21′. This is perhaps the only really difficult pair in the list, with a large aperture. The distance given above is not too small.

(9) The attendant is very minute. There are two other stars of about the same magnitude, 227°·1 : 47″·73 and 13°·7 : 56″·48. These should not be confounded with brighter and more distant stars in the same quadrants.

The other pairs are all unequal, but can be observed with moderate apertures.

Chicago, May 25.

On the Position of λ Ursæ Minoris.

By Professor T. H. Safford.

The star in question is extremely well known; but its proper motion and nearness to the Pole make it very troublesome to predict its place; so that it furnishes a good example of the treatment of proper motions in that region of the heavens.

I begin with the assumption of the following formula, as representing its position for time t referred to the Equator and Equinox of 1855 :—

$$\text{A.R.} = 20^{h}\ 8^{m}\ 30^{s}\cdot200 - 0^{s}\cdot073\,(t-1855),$$
$$\text{Decl.} = 88^{\circ}\ 52'\ 32''\cdot30 + 0''\cdot01\,(t-1855).$$

These were derived from a first approximate solution, after reducing to 1855 the material most conveniently at hand.

The first step is to calculate for various epochs the positions which correspond to this formula, after application of precession to the epochs in question.

With the position for 1855,

$$\alpha = 20^{h}\ 8^{m}\ 30^{s}\cdot200,$$
$$\delta = 88^{\circ}\ 52'\ 32''\cdot30,$$

and the following values of the precession-constants $z+\lambda$, $z'-\lambda'$, θ, derived from the data of Bessel's *Tabulæ Regiomontanæ* :—

	$z+\lambda$	$z'-\lambda'$	θ
	′ ″	′ ″	′ ″
1755	−38 25·02	−38 19·54	−33 25·869
1790	25 0·01	24 53·31	21 43·786
1800	21 10·03	21 2·84	18 23·123
1810	17 20·07	17 12·35	15 2·536
1815	15 25·09	15 17·09	13 22·245
1835	7 45·21	−7 35·94	−6 41·104
1855	−5·37	+5·37	0·000
1875	+7 34·42	7 46·85	+6 41·065

By the help of these formulæ,

$$A = \alpha + z + \lambda,$$
$$m \cos M = \cos\delta \cos A,$$
$$m \sin M = \sin\delta,$$
$$\cos\delta' \sin A' = \cos\delta \sin A,$$
$$\cos\delta' \cos A' = m \cos(M+\theta),$$
$$\sin\delta' = m \sin(M+\theta),$$
$$\alpha' = A' + z' - \lambda',$$

were obtained the following values of α', δ', the right ascensions and declinations for the various equinoxes and equators, corresponding to the fixed values for 1855 :—

	α'			δ'		
	°	′	″	°	′	″
1755	319	24	5·34	88	30	25·24
1790	314	28	52·1	88	38	58·86
1800	312	52	28·4	88	41	17·41
1810	311	10	7·2	88	43	31·70
1815	310	16	36·49	88	44	37·13
1835	306	26	4·54	88	48	46·21
1855	302	7	33·00	88	52	32·30
1875	297	19	34·67	88	55	51·35

	A.R. in Time.		
	h	m	s
1755	21	17	36·356
1790	20	57	55·47
1800	20	51	29·89
1810	20	44	40·48
1815	20	41	6·433
1835	20	25	44·303
1855	20	8	30·200
1875	19	49	18·311

The values of the precession, secular variation, and Argelander (Tiele's) third term were then computed for the last four dates, as follows :—

	In A.R.		
	Precession.	Secular Variation.	Third Term.
	s	s	s
1815	−43·4488	−25·772	−209·2
1835	−48·8398	−28·055	−165·1
1855	−54·6192	−29·562	−77·0
1875	−60·5727	−29·678	+ 67·5

In computing these quantities, the tables by Menten and Tiele in vol. vii. of the *Bonn Observations*, and those there referred to in the *Washington Observations* for 1847, were employed; the quantities being modified where necessary to correspond to Bessel's m and n from the *Tabulæ Regiomontanæ*.

In calculating the secular variations, I found it necessary to compute the coefficient of $\tan^2 \delta$ to more decimals than the table gives. This coefficient is

For 1755 [8·11432] sin 2α

1875 [8·11381] sin 2α,

Menten's table gives to four places the logarithm of [8·1139] sin 2α.

The similar coefficients in declination are

	Precession.	Secular Variation.	Third Term.
	"	"	"
1815	+12·9671	−4·838	−69·2
1835	11·9115	−5·734	−79·8
1855	10·6604	−6·751	−88·7
1875	+ 9·2051	−7·752	−93·8

The third term, as calculated by the help of Tiele's table, is not to be depended upon in its last place at so high northern declinations; but as it is the coefficient of $\left(\frac{t}{100}\right)^3$ in the development according to powers of the time, this does not matter much for an interval of ten years before or after the epoch.

Multiplied by ·06 this "third term" gives us the secular variation of the secular variation, as can be easily shown by Taylor's theorem, and roughly controlled by the values given.

Of more consequence is sometimes the fourth term in the development. If we wish to proceed, say from 1835 to 1845, we can interpolate the third term roughly for one-fourth the interval; or in this case from 1835 to 1837·5; which gives us -156^s for its value at the last date. Using this value we shall take into account the fourth term so far as is needful. Then the A.R. for 1845 will be

	h	m	s
A.R. 1835	20	25	44·303
10 × Precession		−8	8·398
$\frac{1}{2}$ × Secular Variation			−14·027
$\left(\frac{10}{100}\right)^3$ × Third Term			−0·156
A.R. 1845	20	17	21·72

The next step is to compute the effect of proper motion, assumed as $-0^s·073$ and $+0''·01$ annually, referred to the planes of 1855.

To refer them to any other plane the formulæ will be

$$\sin \xi = \frac{\sin \theta \sin A'}{\cos \delta},$$

where A′ is $a'-z'+\lambda'$ before used, and δ is the declination for 1855.

Then if

$$\Delta\alpha = -0^s·073\,(t-1855) = -1''·095\,(t-1855),$$
$$\Delta\delta = +0·01\,(t-1855),$$

we shall have

$$\Delta\alpha' \cos\delta' = \Delta\alpha \cos\delta \cos\xi + \Delta\delta \sin\xi,$$
$$\Delta\delta' = -\Delta\alpha \cos\delta \sin\xi + \Delta\delta \cos\xi.$$

These formulæ give us the following results:—

	$\Delta\alpha'$	$\Delta\delta'$	ξ
	s	s	° ′
1790	+51·41	−0·952	+13 11·44
1800	+45·82	−0·774	+11 27·32
1810	+39·47	−0·605	+ 9 37·27
1815	+36·00	−0·525	+ 8 39·90
1825	+28·41	−0·373	+ 6 40·29
1835	+19·91	−0·233	+ 4 33·94
1845	+10·45	−0·109	+ 2 20·59
1855	0·00	0·000	
1865	−11·46	+0·091	− 2 27·97
1875	−23·89	+0·161	− 5 3·39
1885	−37·25	+0·210	− 7 46·24

For 1755 the values of $\Delta\alpha'$ and $\Delta\delta'$, $+65''\cdot96$ and $-1''\cdot63$ respectively, were obtained by a direct computation, using

$$\alpha = 302\ 9\ 22\cdot50$$

and

$$\delta = 88\ 52\ 31\cdot30.$$

The next step is the comparison of these computed places with observation, carried out as follows:—

	Computed A.R.	Computed Decl.	
	° ′ ″	° ′ ″	
1790	314 28 52·1	+88 38 58·86	With precession alone.
	+51·41	−0·95	Effect of proper motion.
	314 29 43·51	+88 38 57·91	Sum: Computed place.
	h m s		
	20 57 58·90		
Fedorenko's Catalogue	20 58 2·38	88 38 57·76	Observed place.
Computed—Observed	−3·48	+0·15	

In this case the proper motion from the date of observation to the epoch is neglected.

In the following table are given the comparisons for which I have materials at hand. The principal observations wanting are Piazzi, Greenwich, 1868–1872, and various modern series not yet combined into Catalogues; a few positions here given are derived at second-hand from former investigations by myself or others; and several of the places in the table need revision and correction for the adopted nutation:—

	Δα s	Δα cos δ ″	Δδ ″	No. Obs.
Bradley 1755	−0·79	−0·31	+0·21	3
Fedorenko 1790*	−3·48	−1·23	+0·15	2
Groombridge 1807*	+1·75	+0·58	+0·8	Error in Radcliffe?
Struve 1815*	+0·4	+0·13	...	4
Schwerd 1828*	0·0	0·00	−0·10	11
Catalogus Aboensis 1830	+0·04	+0·01	+0·25	17
Cambridge 1832	+3·67	+1·15	...	14
Pond 1833	−0·77	−0·24	+0·25	20, 24
Cambridge 1835	...	...	+0·20	17
Taylor 1835	+0·97	+0·30	+1·13	2, 3
Henderson 1838	−0·35	−0·11	−0·08	26, 39
Challis 1838	...	...	+0·30	32
Airy 1840	−1·54	−0·47	+0·05	25, 77
Armagh 1843	+0·56	+0·17	...	36
Radcliffe 1843	...	...	+0·48	158
Airy 1845	−1·55	−0·47	+0·21	15, 56
Pulkova 1845	+0·17	+0·05	+0·16	21, 5
Radcliffe 1847	−0·26	−0·08	...	111
Airy 1851	−1·27	−0·38	−0·08	49, 106
Armagh 1851	...	...	−0·26	5
Carrington 1855	+0·3	+0·09	−0·3	27
Yarnall 1856	...	...	+0·18	117
Airy 1857	−0·72	−0·21	+0·19	80, 123
Paris 1857*	+0·23	+0·07	−0·24	50, 59
Airy 1864	+0·40	+0·12	+0·24	30, 84
Pulkova 1868	+0·24	+0·07		
Leiden 1868	...	...	+0·14	40
Washington 1870	−0·14	−0·04	+0·19	104, 177
Rogers 1872	−0·84	−0·24	+0·18	20, 12
Airy 1874	+0·95	+0·27	−0·16	36, 91

The authorities marked with an asterisk are taken at second-hand from others' investigations or my own. There seems to be an error of 1″ to 2″ in the reduction of Groombridge's Polar Distance to 1845, as found in the Radcliffe Catalogue.

To reduce the values of Δα to the parallel the following little table of log (15 cos δ) was found serviceable :—

Year.	(log 15 cos δ.)	Year.	(log 15 cos δ.)
1755	9·592	1835	9·492
1790	9·548	1855	9·469
18	9·516	1875	9·447

My first intention was to assign weights and proceed to a solution of equations of condition, thus correcting the assumed position; but the resulting corrections were found to be very small, and I have judged it best to wait until I can add all the observations to be found in Catalogues which I do not possess. The experiments which I made led mainly to the conclusion that the formulæ heretofore given cannot be much improved at present, at least with any certainty.

In carrying the calculations forward for the next few years, the following values for 1885, depending on the same elements, will be found useful:—

	A.R. h	m	s	Decl. °	′	″
Value without P.M. from 1855	19	38	57·84	+88	57	19·39
Annual Precession			−63·5110			+8·3917
Secular Variation			−28·998			−8·415
Third Term			+162·2			−93·6

The effect of P.M. from 1855 up to the year of observation should be interpolated from the previous table and added to the values derived from these numbers.

In case the arrangement of the calculation given in this paper shall save anyone else the annoyances which I have undergone in the solution of similar problems, my object will have been gained; the points of originality in the process are of course few and small.

The star's place itself would seem not to require so many observations as have been made for a few years, but rather such as shall individually possess the greatest possible accuracy.

Williams College,
Williamstown, Mass., U.S.A.,
May 15, 1878.

A Reply to Mr. Proctor's Note in the March Number of the Monthly Notices. By E. J. Stone, M.A., F.R.S., Her Majesty's Astronomer, Cape of Good Hope.

1. Mr. Proctor's remarks in the March No. on my paper in the January No. appear to call for some reply on my part.

In Mr. Proctor's paper in the Supplementary No. of the *Notices*, 1877, he says that he has proved "that by no optical contrivances can apparent brightness be increased, though quantity of light can, of course, be greatly increased." I stated in my note in the January No. that this statement requires qualification; for, if it were true, why could not the satellites of *Mars* be as easily seen with a 4-inch telescope as with the 26-inch of the Washington Observatory? Mr. Proctor's answer to this is that my question contains its own answer, viz. "that quantity of light is, of course, greatly increased when the larger telescope is used." But the satellites would not be visible with the large telescope rather than with the small one unless their apparent

brightness was also increased. It will be seen, therefore, that Mr. Proctor's answer directly proves my statement that his general proposition requires qualification and is not applicable to such objects as the satellites of *Mars*; and anyone who will refer to my paper in the January No. will see that my object in bringing this point forward was simply to show that Mr. Proctor's statement required qualification before we could apply it to the case of distant stellar clusters, which was the subject of consideration in my paper. Although I have not mentioned anything about the theory of diffraction disks directly, anyone acquainted with the subject would see at once that it was the basis upon which my views rested, and the reason of my referring to telescopes of a small aperture and low magnifying power in relation to some "Statements of Mr. Proctor on Irresolvable Clusters."

2. My original paper on "A cause for the appearance of bright lines in the Spectra of Irresolvable Star Clusters" has been misunderstood, and therefore could not have been explained in sufficient detail; but on reference to my original paper in the *Proceedings of the Royal Society*, or the extract from it given in the January No. of the *Notices*, it will be seen that I state that "each star, if isolated, would be surrounded by its own gaseous envelope. These gaseous envelopes might, in the case of a cluster, form over the whole or a part of the cluster a *continuous mass* of gas"; and it is expressly stated that it is with reference to such clusters that the light of the gaseous envelope might ultimately predominate over that of the stellar masses. If the phrase "a continuous mass of gas" means anything, it means what I assert I intended it to mean in the January No., viz. that the clusters were physically close and not merely optically close, and I think that the qualifications with which Mr. Proctor admits that he does not doubt that I really meant in my original paper what I asserted that I meant in the January No. would have been better omitted.

1878, *May* 13.

Note on Dr. W. Erck's Observations of the Outer Satellite of Mars. By A. Marth, Esq.

In consequence of an unnoticed innovation in the dating of two of Dr. Erck's observations of the satellite of *Mars*, the computed angles of position given on page 365, for September 16 and 26, do not refer to the times of the observations, which were really made 24 sidereal hours earlier. When making the computations, I had not the text of Dr. Erck's communication before me, but merely an extract containing the assigned times and position angles, and therefore I took September 16, $1^h\ 0^m$ G.S.T. to mean, as usually, $1^h\ 0^m$ G.S.T. on September 16, as I was not aware of Dr. Erck's deviation from the customary reckoning of dates. It appears, however, from a reference to the text, and from a further communication made

by Dr. Erck, that in order to conform with established custom the dates should be September 15 and 25, and that, in consequence, for the lines

			Obs.	Comp.
	h m		°	°
Sept. 16	1 0	G.S.T.	238	267·1
26	0 35		255	322·4

must be substituted

	h m	°	°
Sept. 15	1 0	238	240·2
25	0 35	255	256·1

so that, instead of the previous discordance, there is excellent agreement between the observed and computed angles of position.

Mr. W. S. Franks, of Leicester, has presented to the Society, through the Rev. T. W. Webb, a "Catalogue of the Colours and Magnitudes of 3,890 Stars between the North Pole and 25° South Declination," from observations made by him between July 24, 1877, and May 3, 1878, with an equatoreally mounted refractor of 5 inches aperture and 78 inches focal length, the object-glass being a fine one, by Wray. The eye-piece generally employed was an Aplanatic, by Horne and Thornthwaite, giving a magnifying power of 105, higher powers being occasionally used in the case of close double stars.

In regard to the work Mr. Franks says:—"My method of observing was to take one hour in R.A. as the limit of the sweeps, and commencing at 25° South Declination, examine each zone of 5° in declination at a time, gradually working up to the Pole. In doing so I endeavoured, as much as possible, to follow the natural grouping of the stars in preference to a rigid adherence to their strict sequence in Right Ascension." The independent estimates of magnitude were checked by a comparison with surrounding stars, for which Mr. Franks found a good opera-glass very useful. The works most frequently used for reference were Proctor's large and small Star Atlases, the large maps of the Useful Knowledge Society, Argelander's *Uranometria Nova*, the British Association Catalogue, and Webb's *Celestial Objects for Common Telescopes*."

The Catalogue is arranged in accordance with the method adopted in making the observations, a method perhaps not the most convenient for ready reference, but, as the stars are arranged in hours of R.A. and the name and B.A.C. number of each is given, the identification of any object is sufficiently easy. Each page contains seven columns, giving the B.A.C. number, the constellation, the B.A.C. magnitude, the observed magnitude, the colour, remarks, and the date of observation.

The work, which is the outcome of a good deal of painstaking labour on the part of Mr. Franks, will be bound and placed in the Library for convenience of reference by workers in the same field of observation.

G. K.

THE SPHEROMETER CALIPER.

Fig. 1.

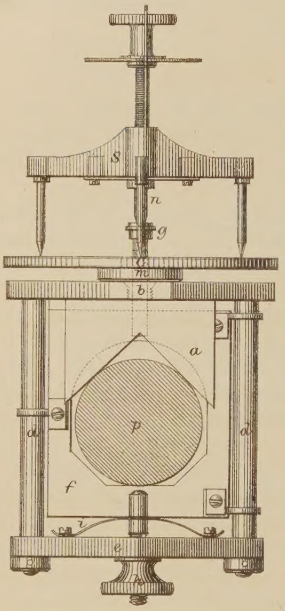


Fig. 2.

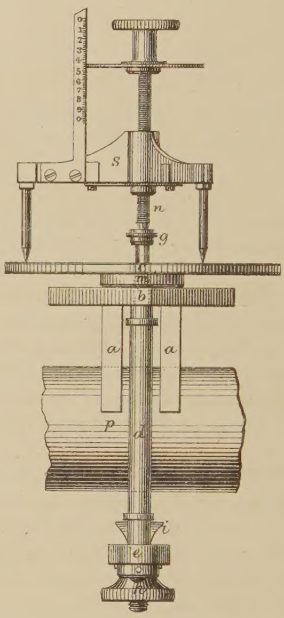


Fig. 3.

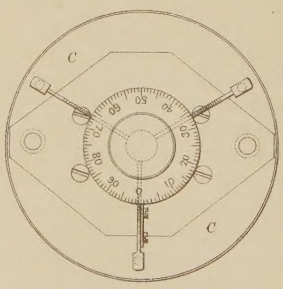
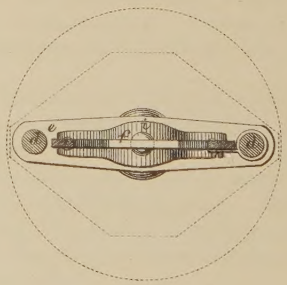
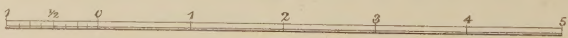


Fig. 4.



Scale



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